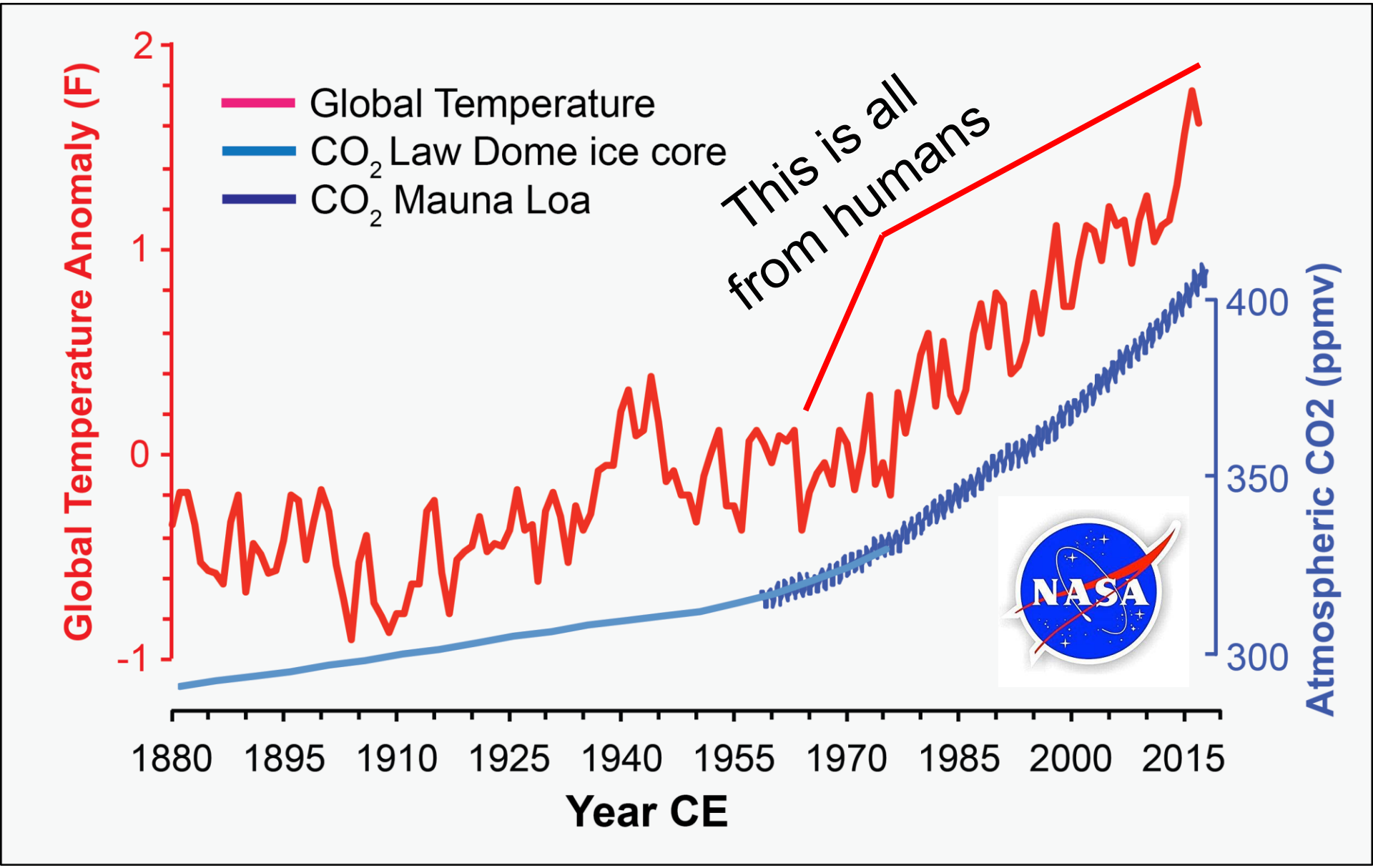
# Downpours and Droughts: Changing Extremes in a Warming World

Dr. Erich Osterberg
Dartmouth College Earth Sciences

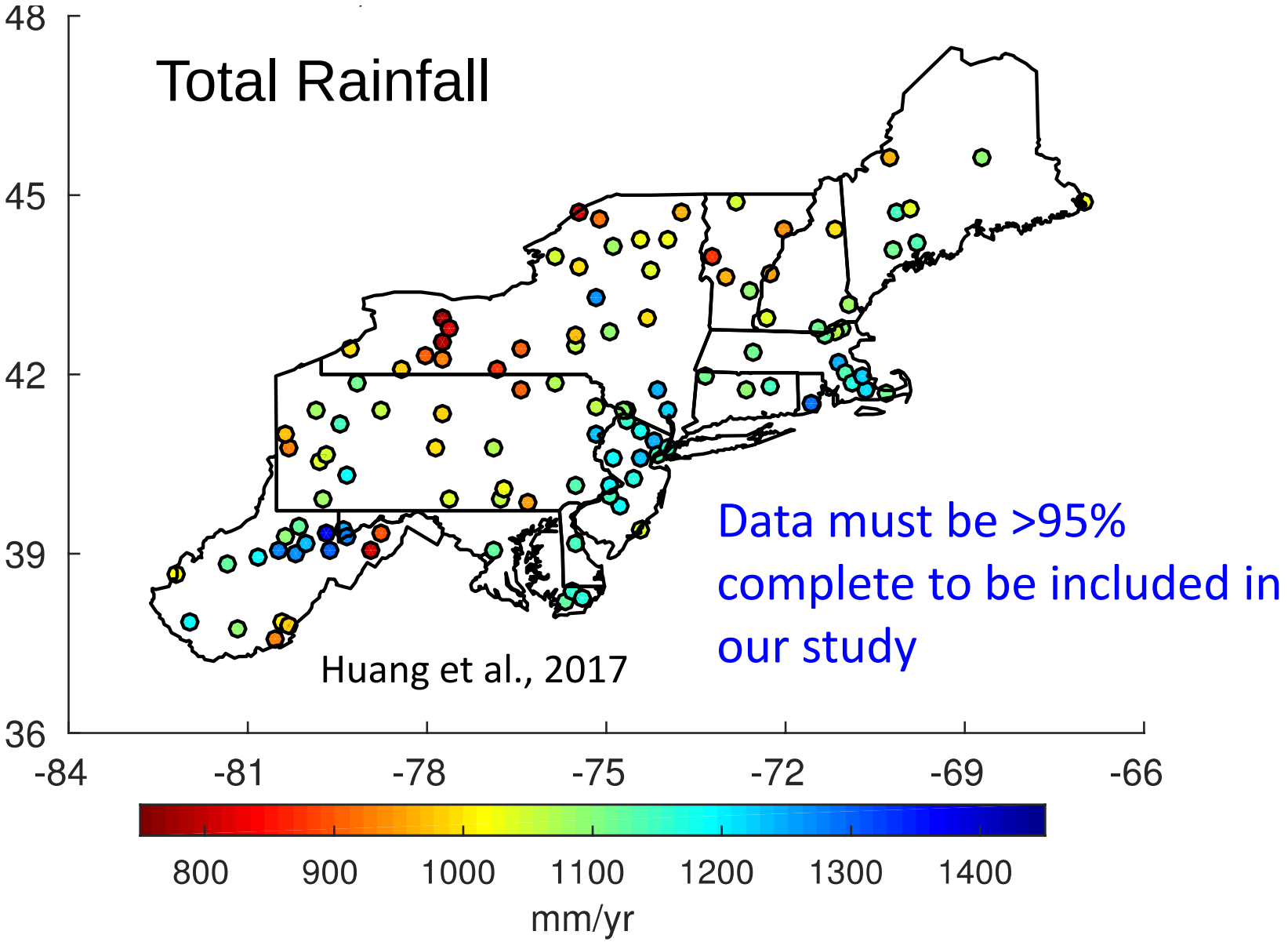
# The Earth Has Warmed ~2°F since 1900



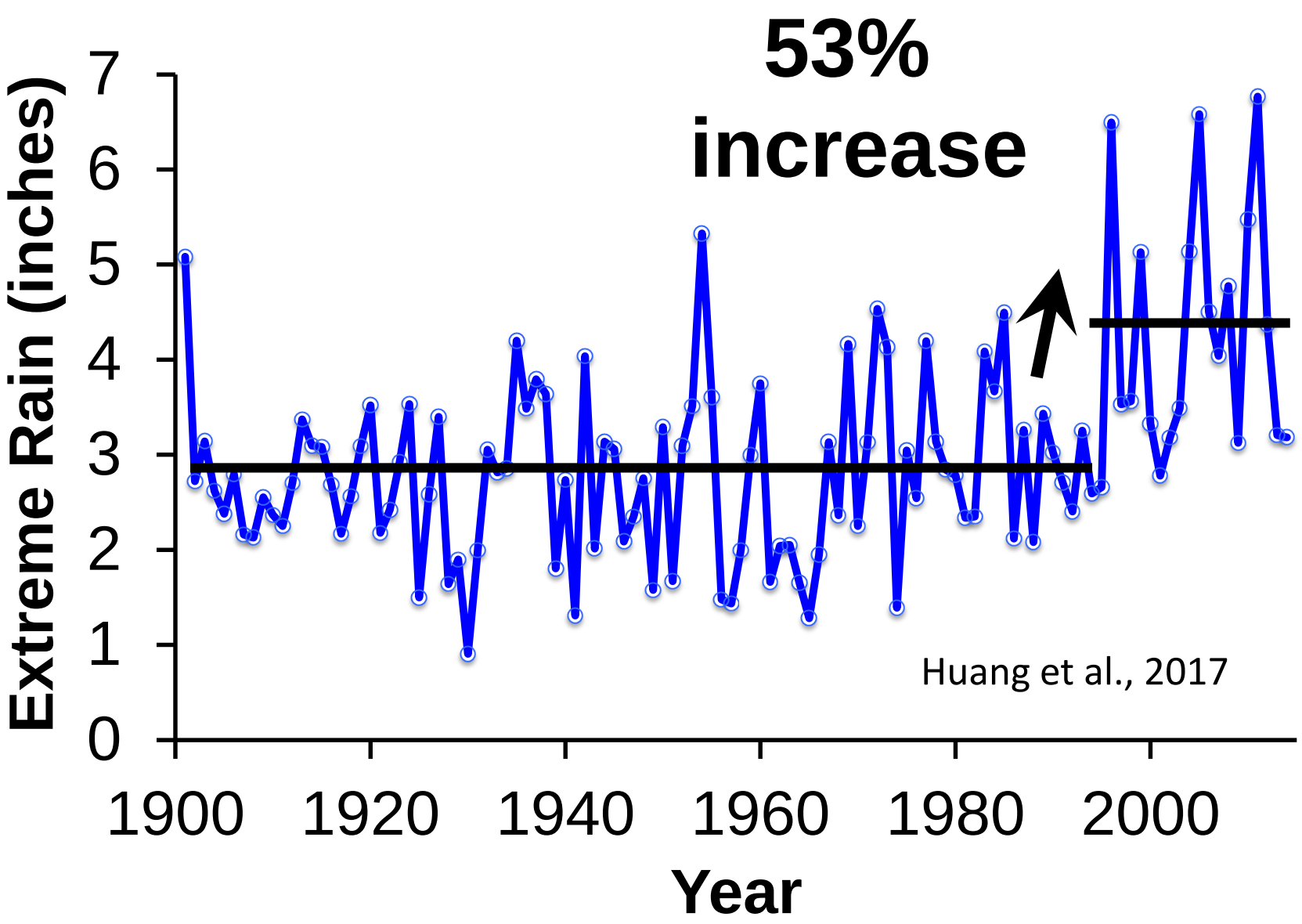
# Take Home Messages

- Downpours (extreme rainfall) jumped up 50% in 1996
  - Caused by Hurricanes, Nor'easters and thunderstorms
- Drought is more frequent in NH & VT than you may think and has real impacts
- The future:
  - More downpours likely
  - More summer drought?

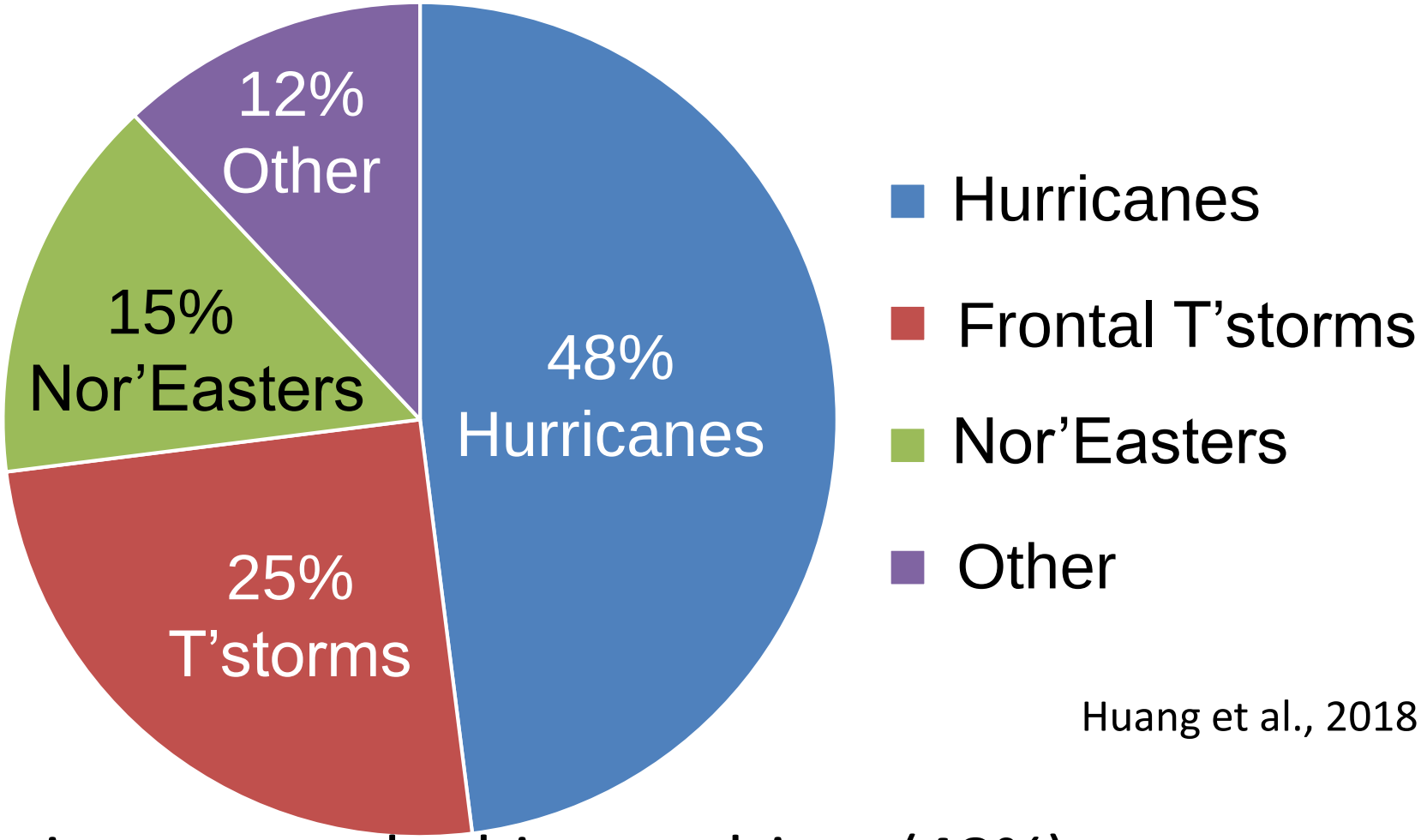
# We Studied Rainfall Data from the Best 116 Weather Stations spanning 1900-2014



# Extreme Rainfall Jumped 53% in 1996



# Which Storms are More Extreme since 1996?

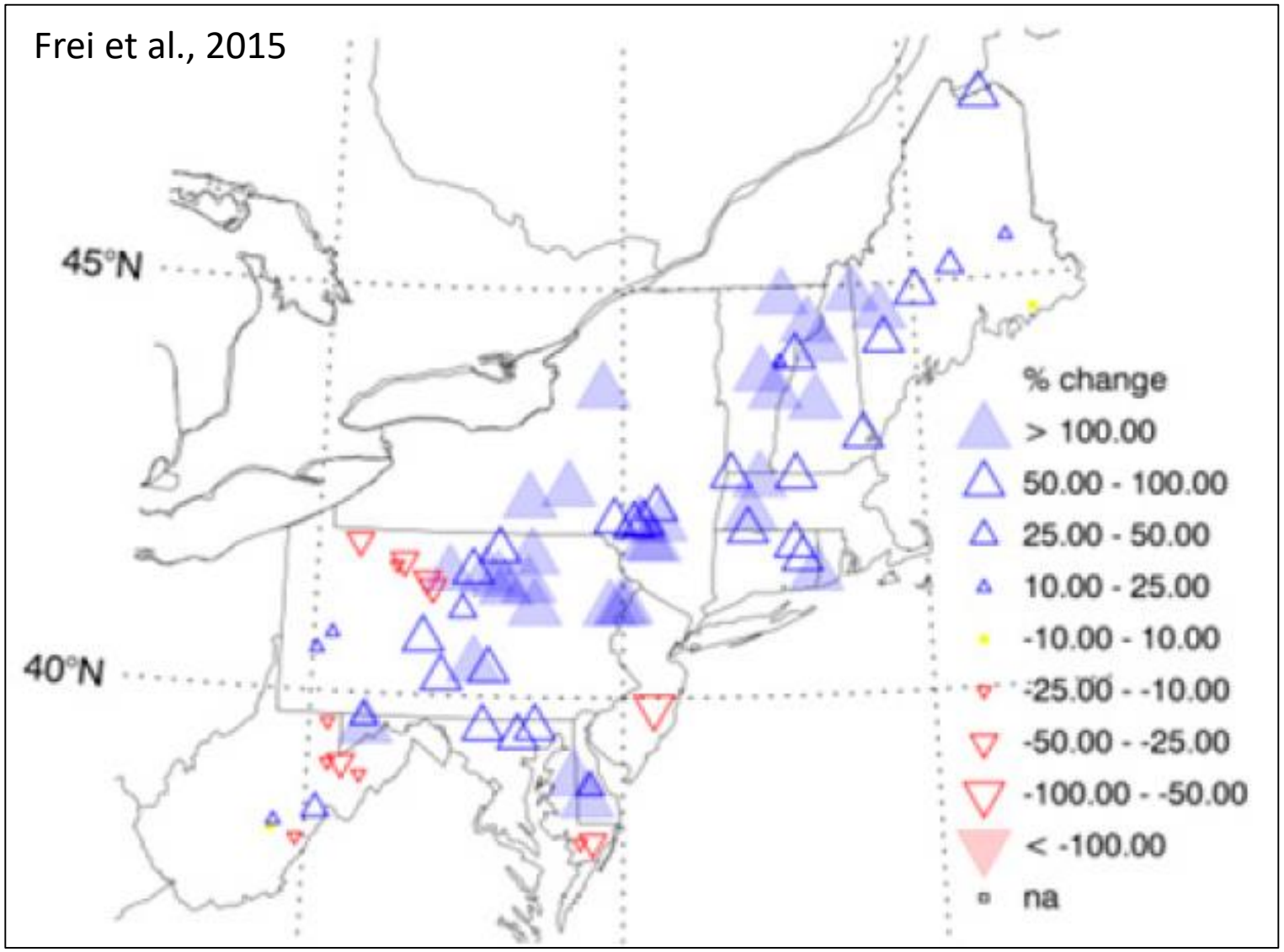



Huang et al., 2018

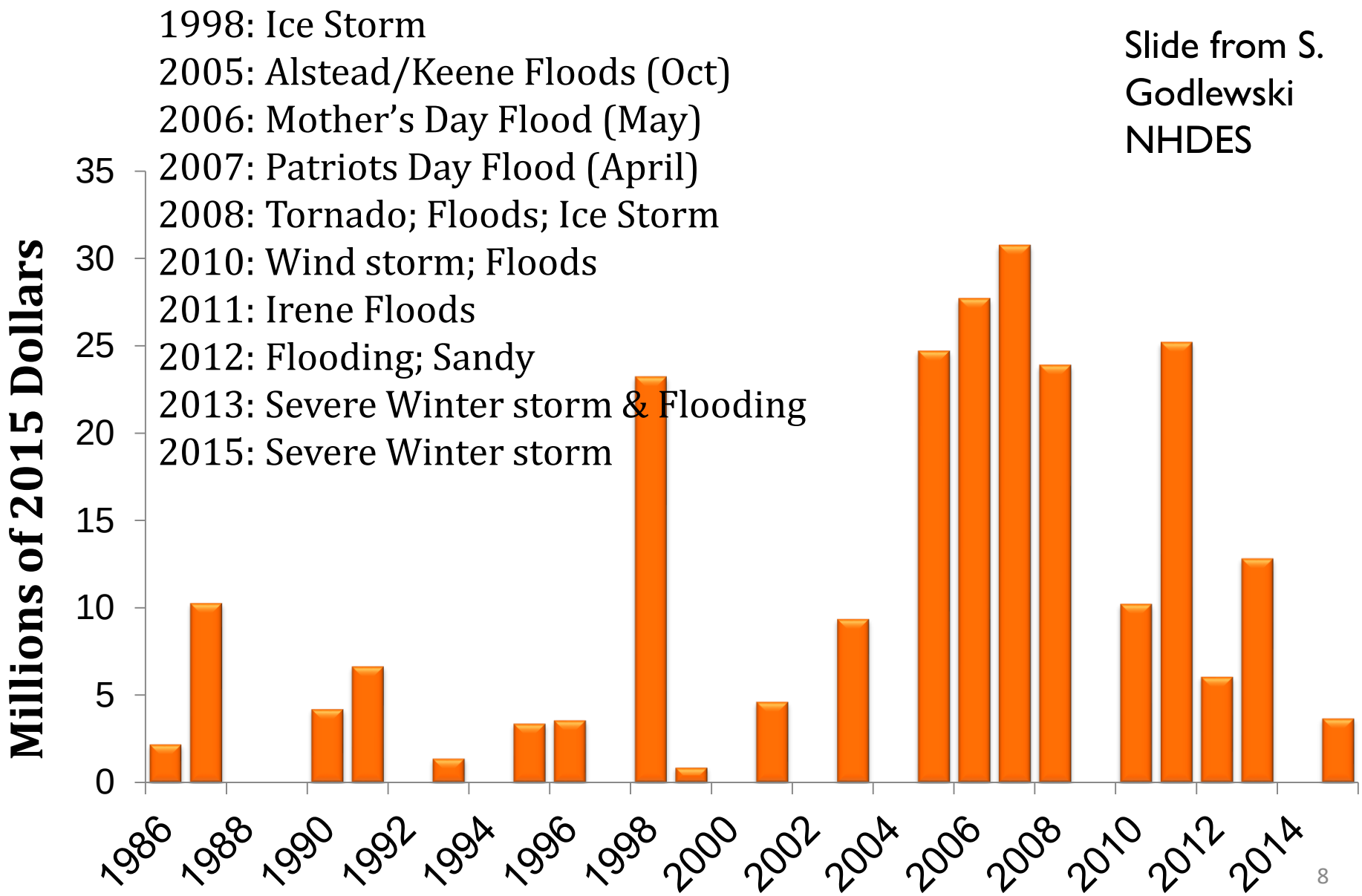
- Hurricanes are the biggest driver (48%)
- T'storms (25%) and Nor'Easters (15%) also causing more extreme rainfall

# Summer Flooding is Increasing in Response

% Change in Summer Extreme Streamflow Events
in 2001-2012 compared to 1977-1988



# Federal Disaster Spending in New Hampshire



*U.S. Drought Monitor*

# Northeast

**July 17, 2018**

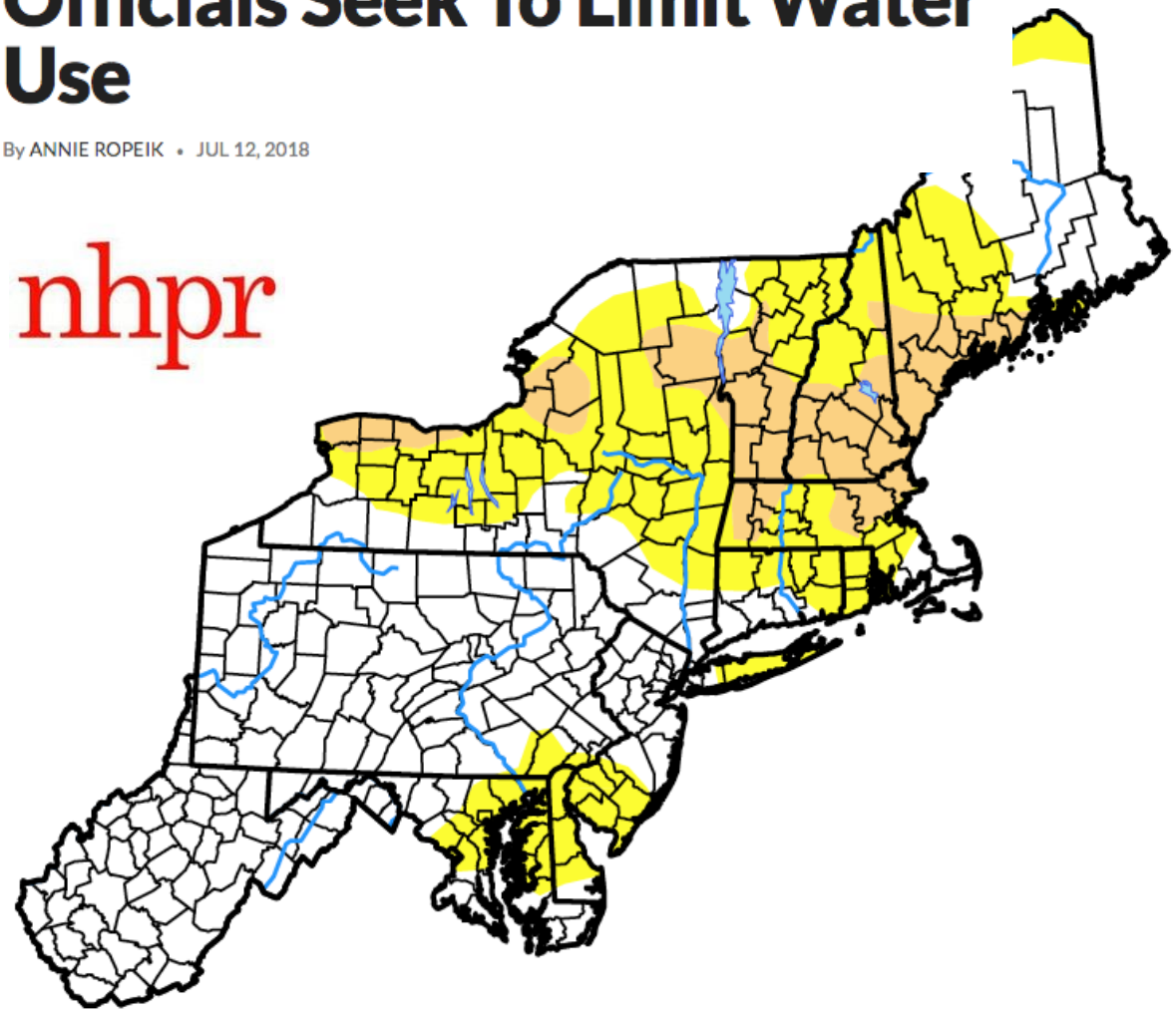
***(Released Thursday, Jul. 19, 2018)***

**Valid 8 a.m. EDT**

## As N.H. Drought Spreads, Officials Seek To Limit Water Use

By ANNIE ROPEIK • JUL 12, 2018

nhpr



## *Intensity:*

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought


*Author:*

Eric Luebehusen

U.S. Department of Agriculture


**http://droughtmonitor.unl.edu/**

*U.S. Drought Monitor*

# Northeast

**October 23, 2018**

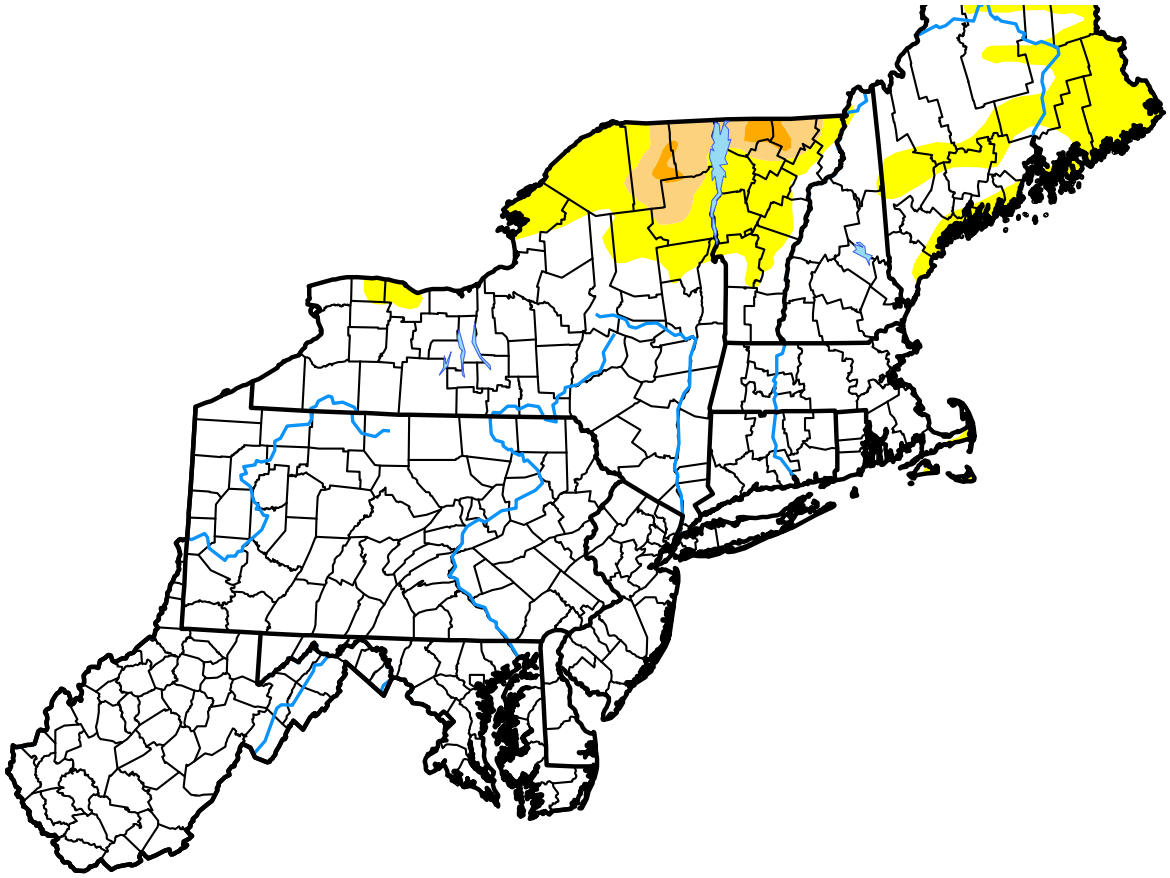
***(Released Thursday, Oct. 25, 2018)***

**Valid 8 a.m. EDT**

Drought continues to plague northern Vermont, leaving farms and wells dry

STOWE REPORTER

By Elizabeth Gribkoff | VTDigger.org Oct 18, 2018



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U.S. Department of Agriculture


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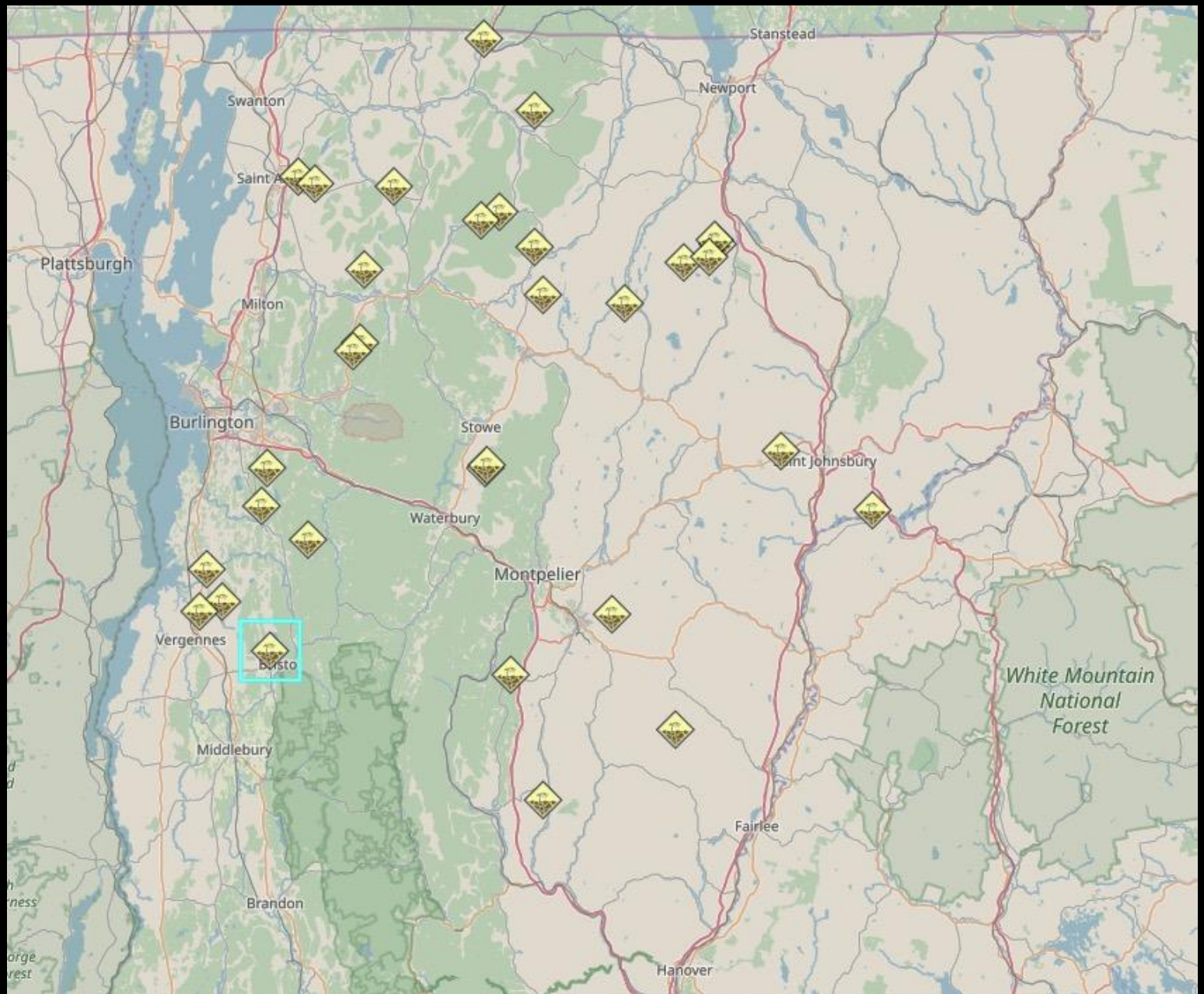
# Some Wells in Northern VT are Currently Failing



*U.S. Drought Monitor*

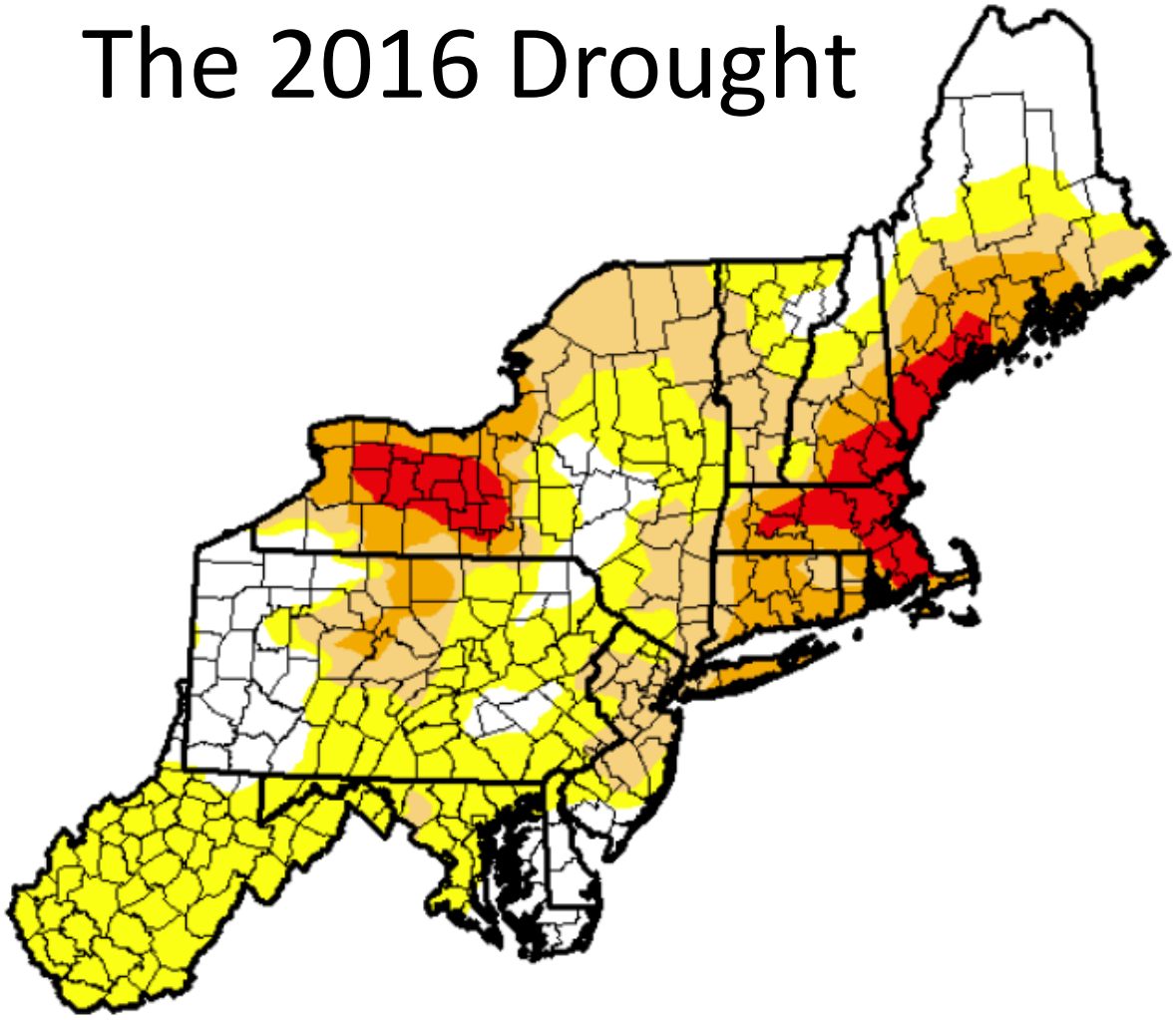
# Northeast

**September 27, 2016**

*(Released Thursday, Sep. 29, 2016)*

Valid 8 a.m. EDT

## The 2016 Drought



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*Author:*

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U.S. Department of Agriculture

**http://droughtmonitor.unl.edu/**

# Drought causes wells to dry up across NH

By Breanna Edelstein bedelstein@eagletribune.com Oct 4, 2016

The Eagle-Tribune

# Wells Across New England Coming Up Dry Amid Drought

By Michael Casey
Associated Press

Thursday, September 22, 2016

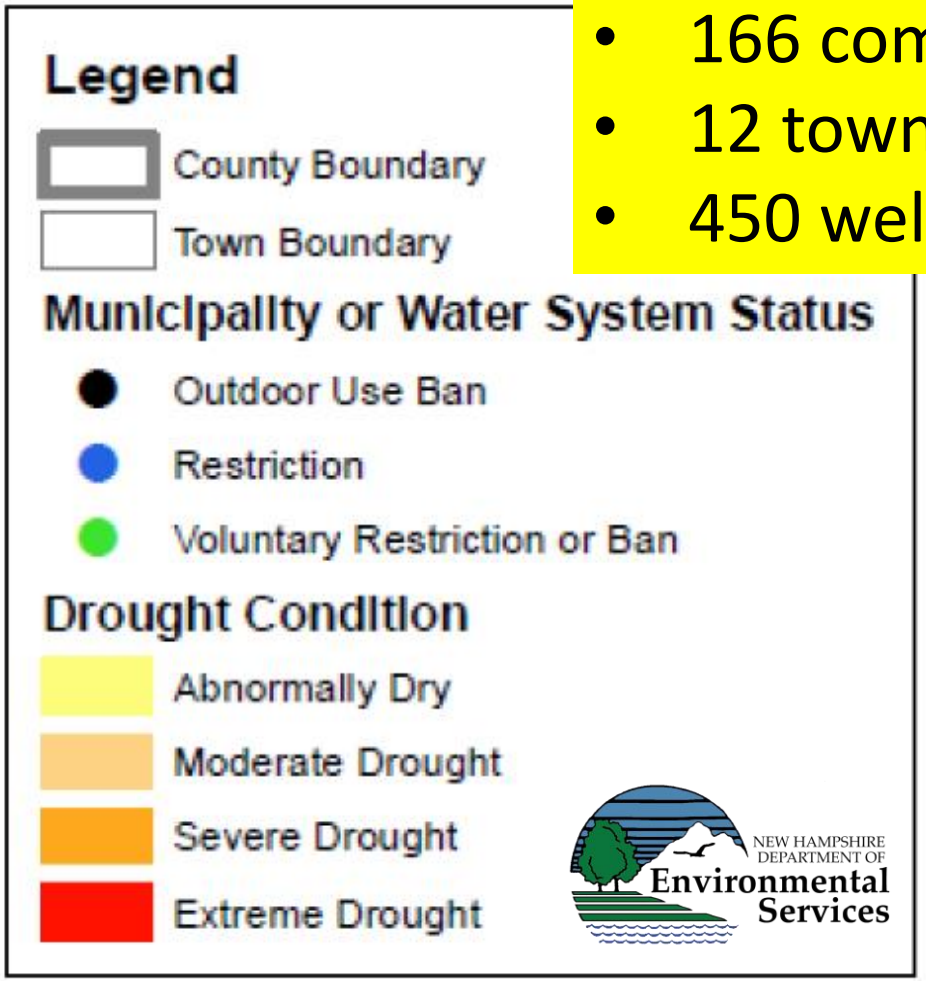
VALLEY NEWS

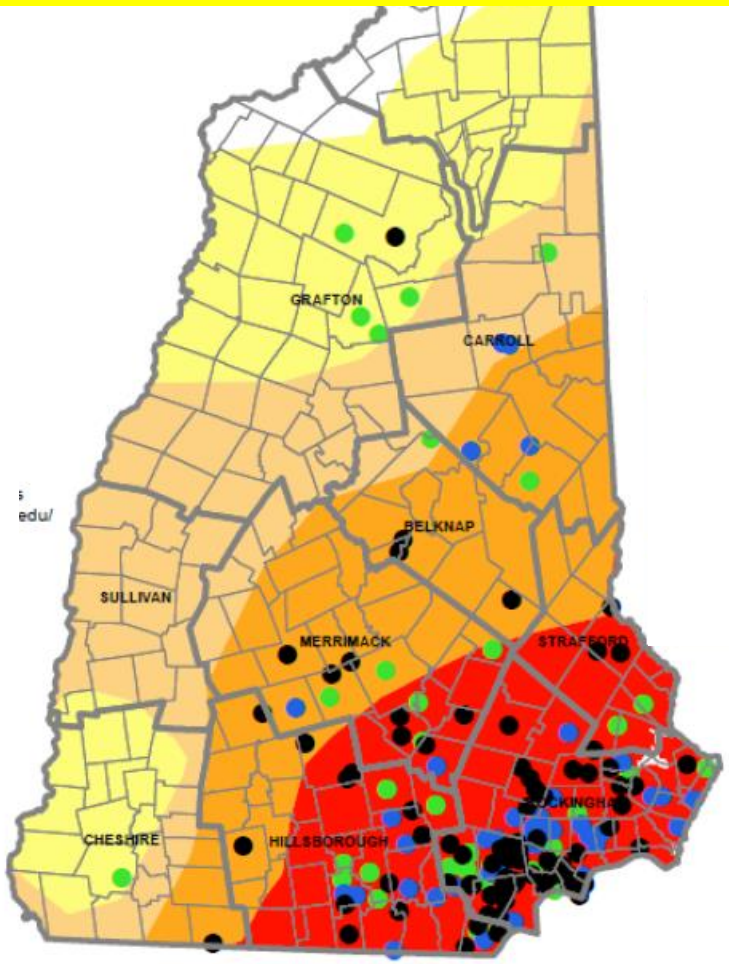
The Boston Globe

# Drought continues to spread across Mass.,

# 2016 Drought: Water Use Restrictions and Bans

- 166 community restrictions or bans
- 12 towns setup emergency water sites
- 450 wells replaced or deepened



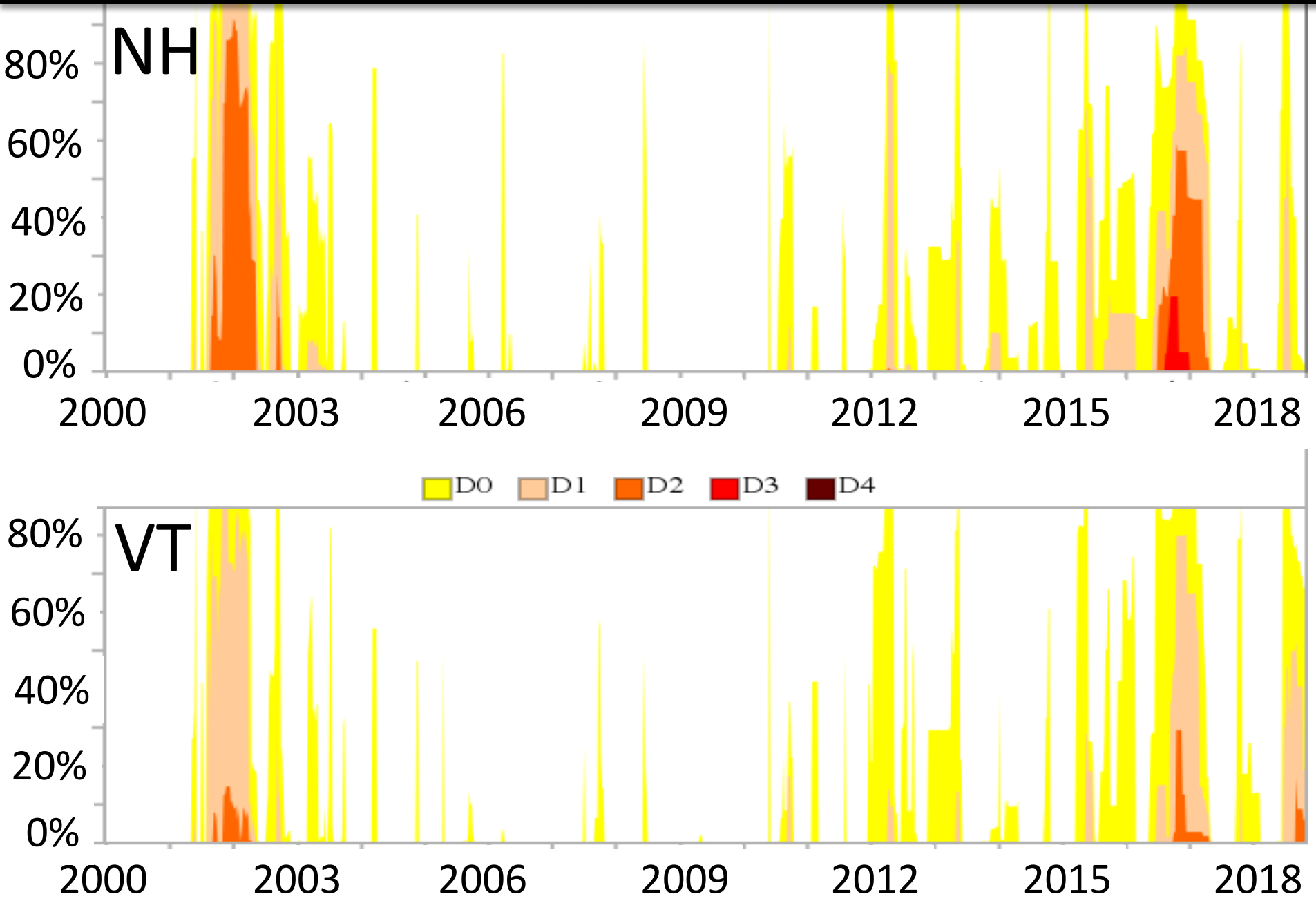
# What do These Drought Classifications Mean?

*Intensity:*

| | |
|---|---|
| D0 Abnormally Dry | Occurs every 6-9 months |
| D1 Moderate Drought | Occurs every year |
| D2 Severe Drought | Occurs every 3 years |
| D3 Extreme Drought | Occurs every 10 years |
| D4 Exceptional Drought | Occurs every 50-100 years |

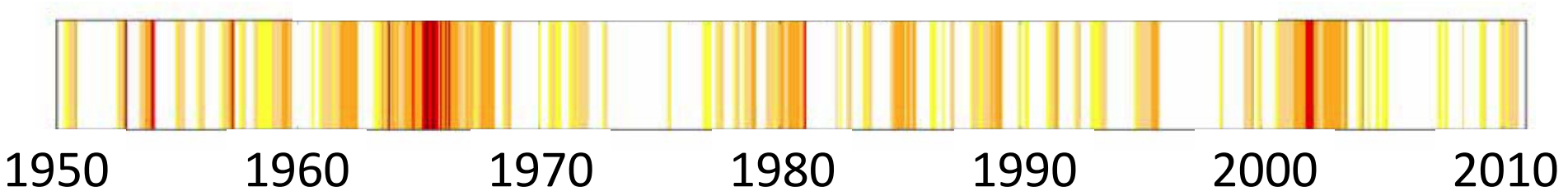
Davis and Stampone, 2014

# NH and VT Drought History: 2000-Today

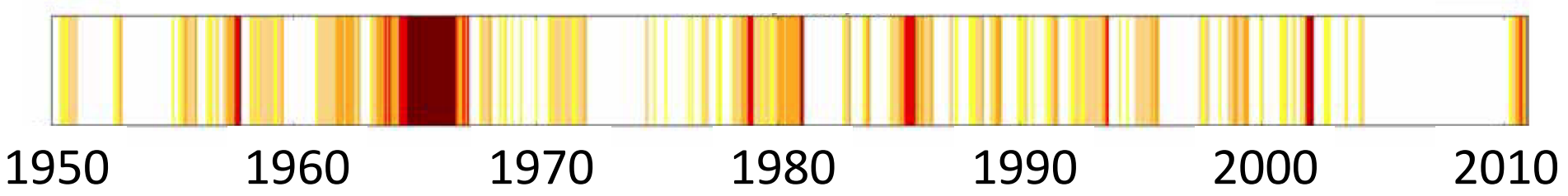


# New Hampshire Drought History

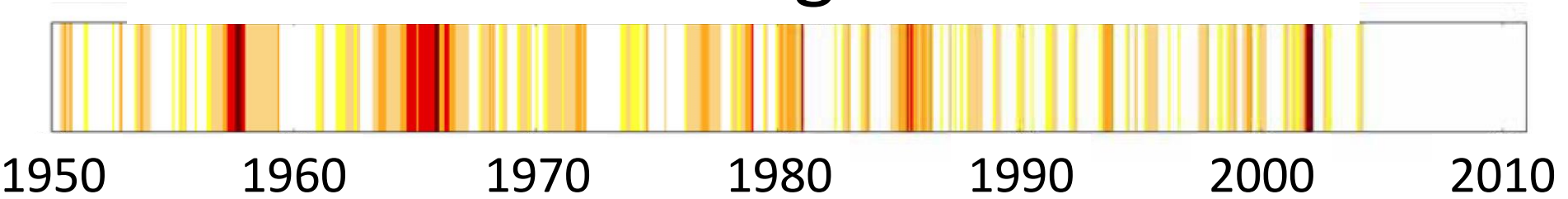
## Grafton & Carroll Counties




## Hillsborough, Merrimack & Belknap

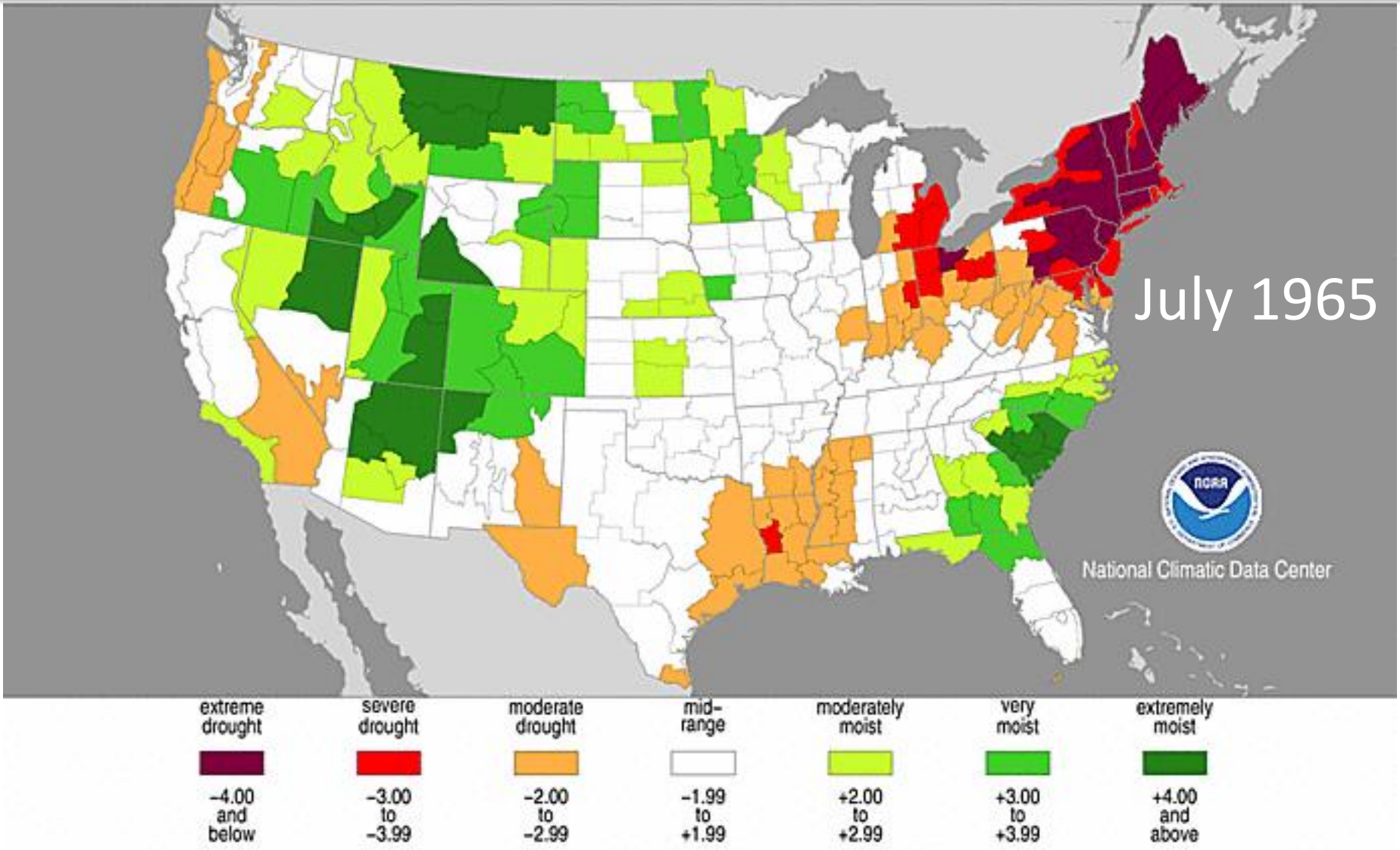



## Stratford & Rockingham Counties

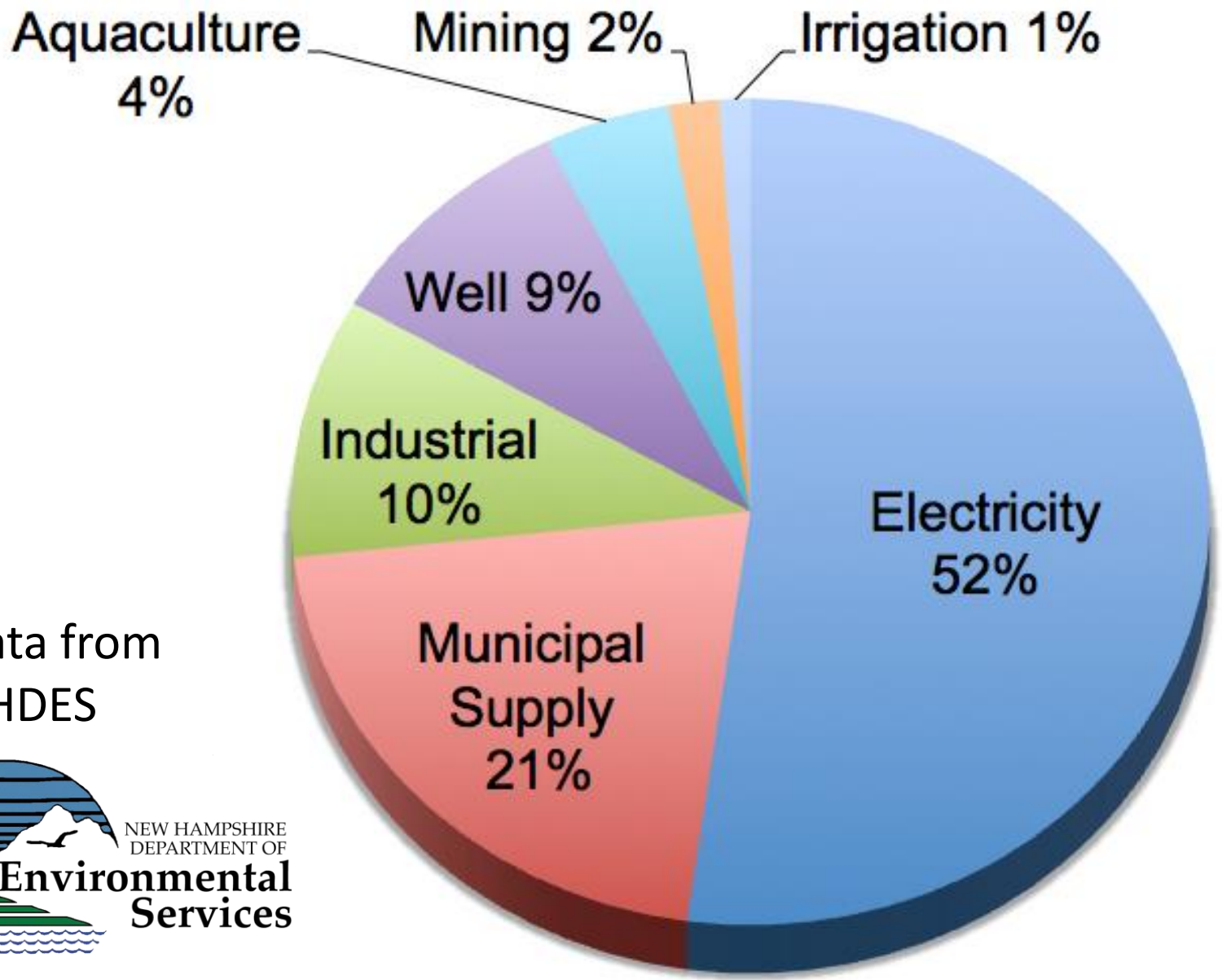



Davis and Stampone, 2014

# Historic Northeast Drought of 1963-1966



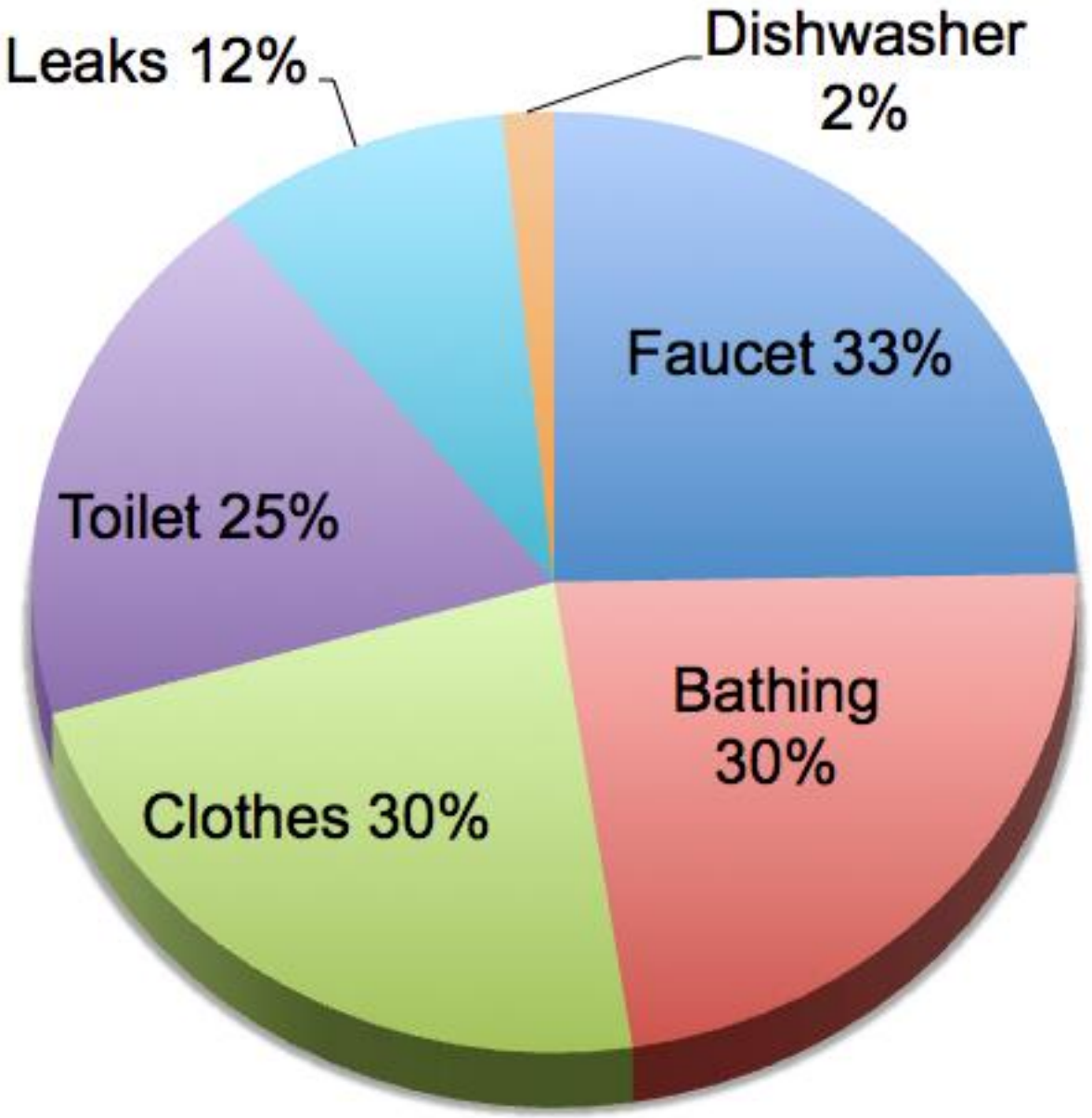
# New Hampshire Water Use Statistics



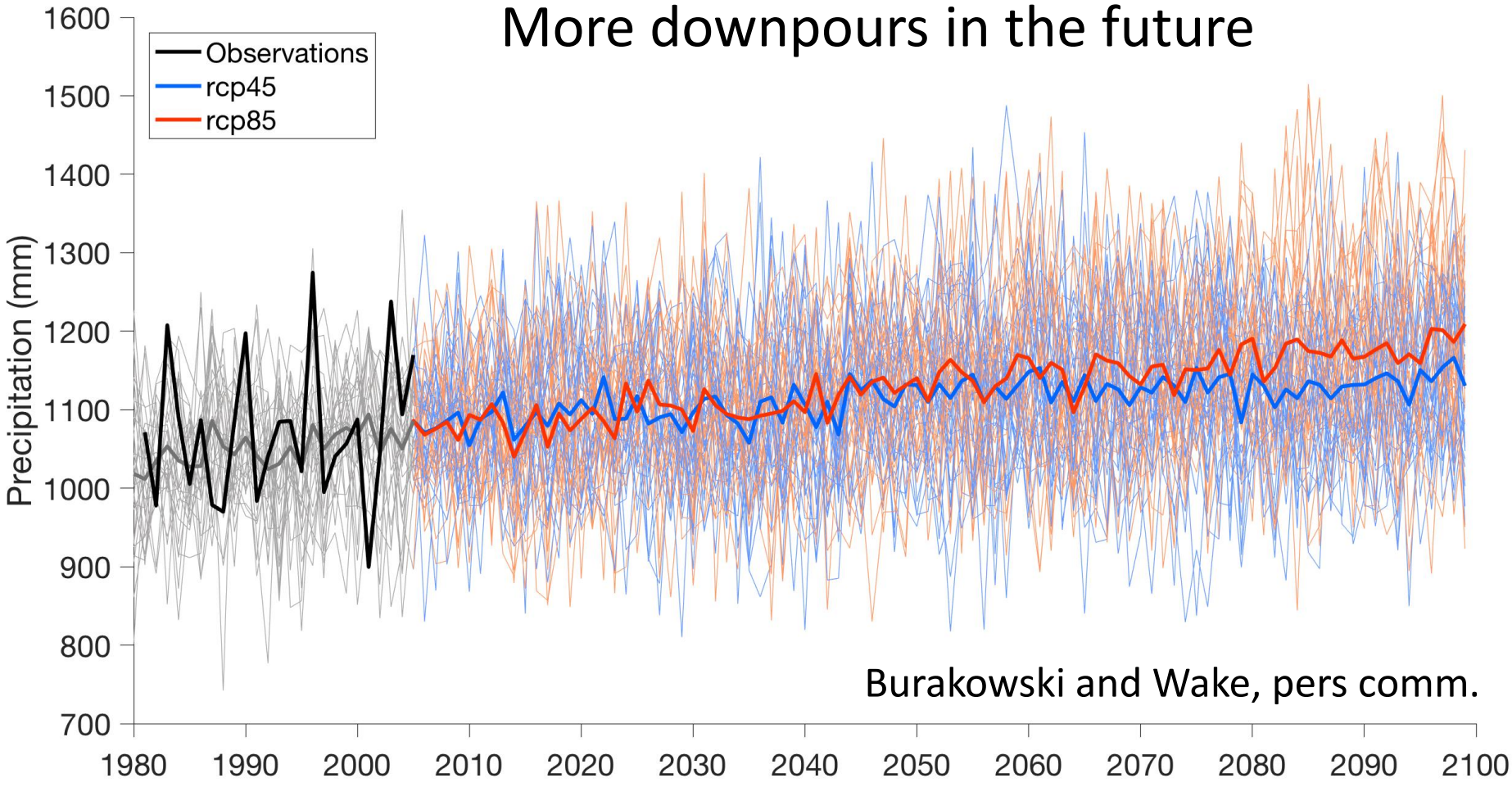

Data from NHDES

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

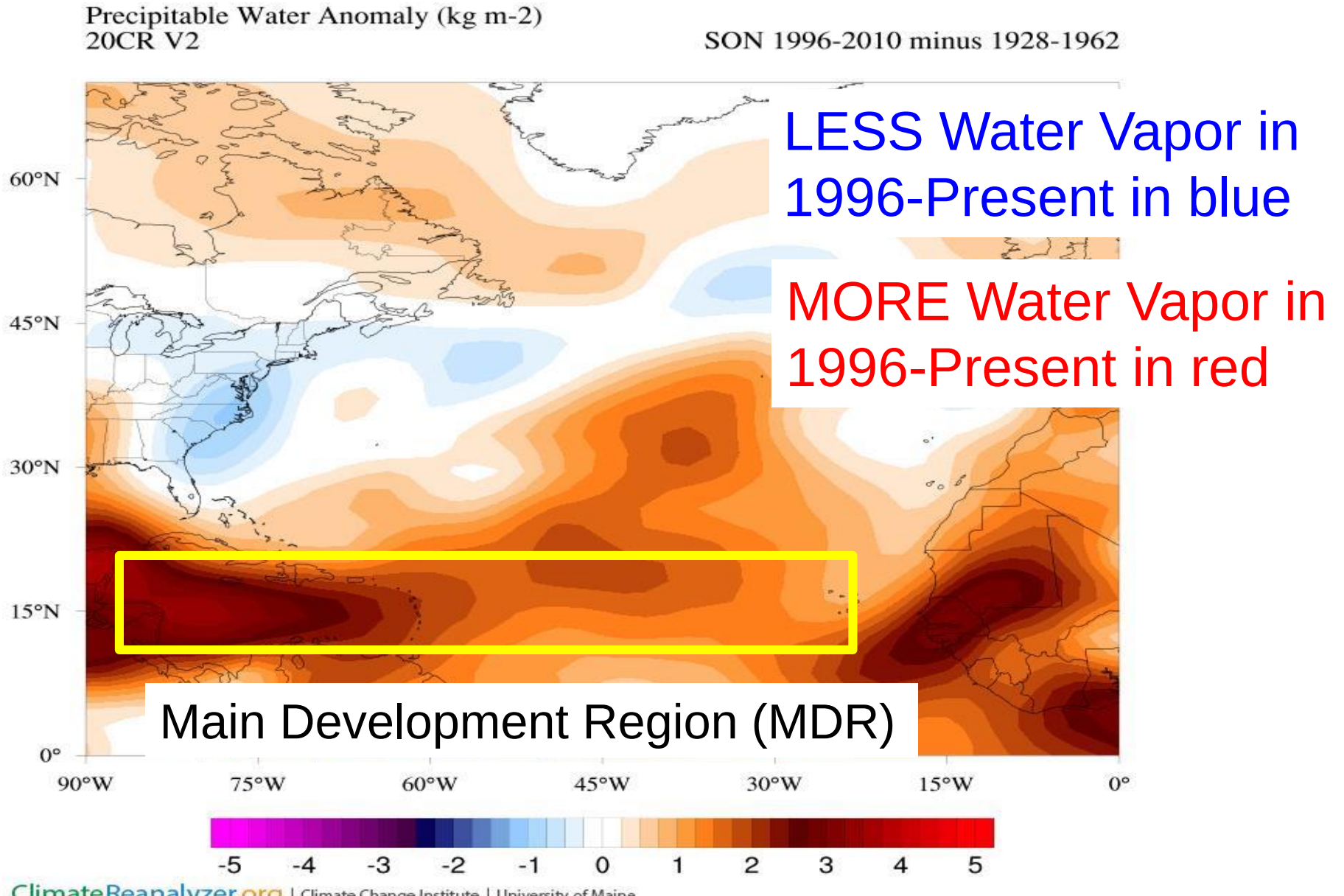
# How Do We Use Our Water at Home?



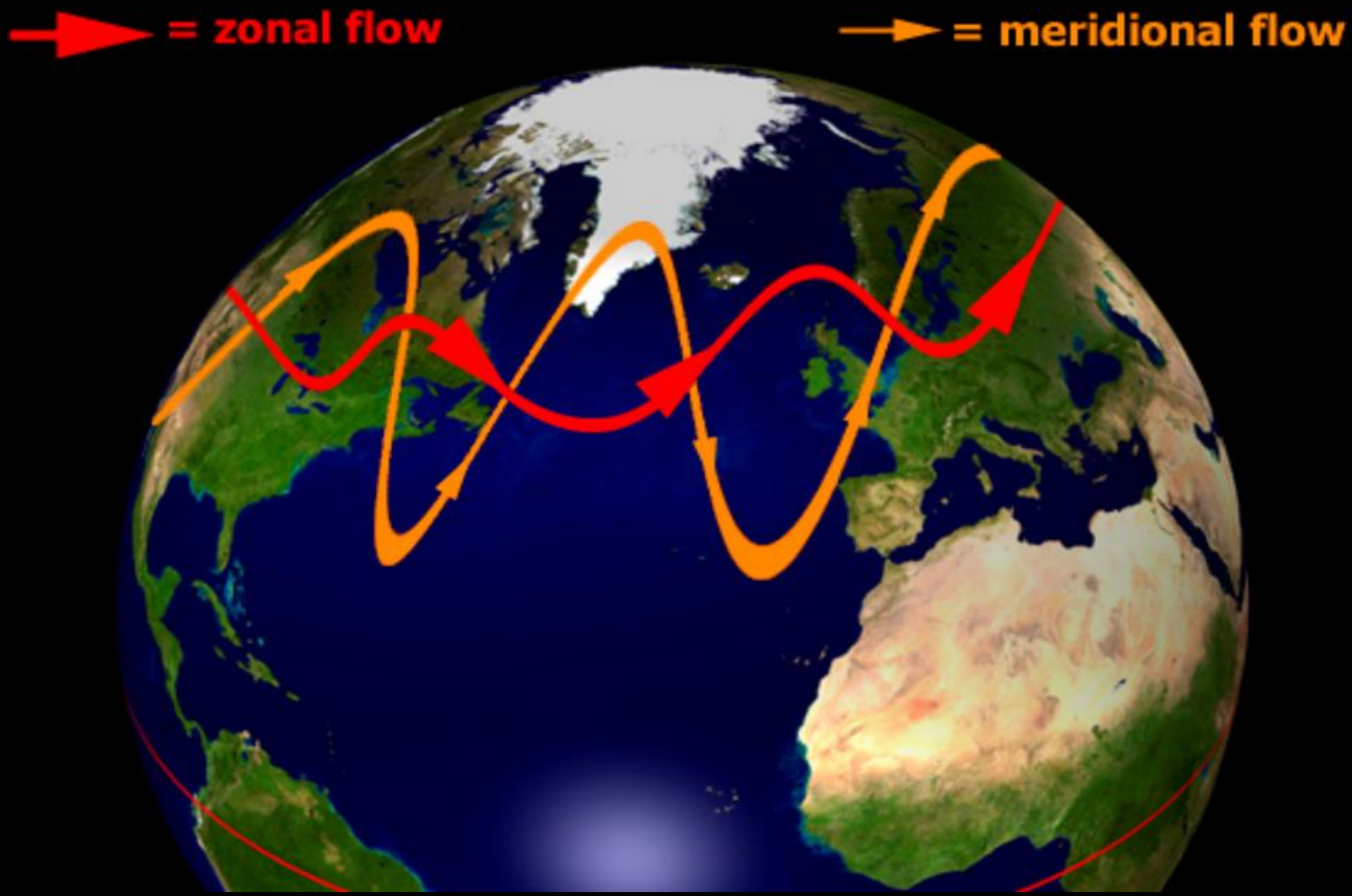
# Climate Models Show the Northeast Getting Wetter Overall in the Future



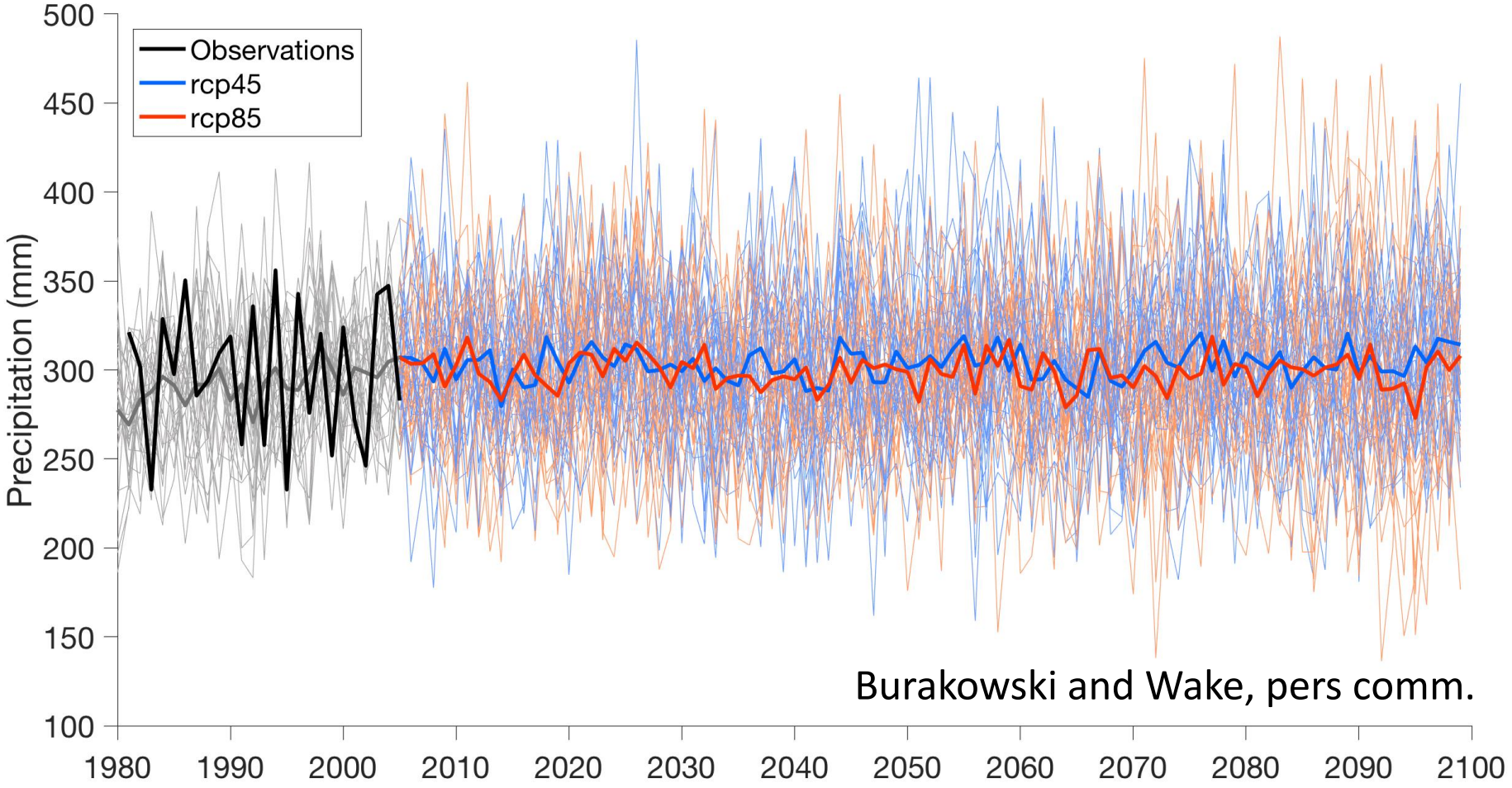
# More Frequent Extreme Rainfall Events from Hurricanes due to Warmer Ocean and More Vapor



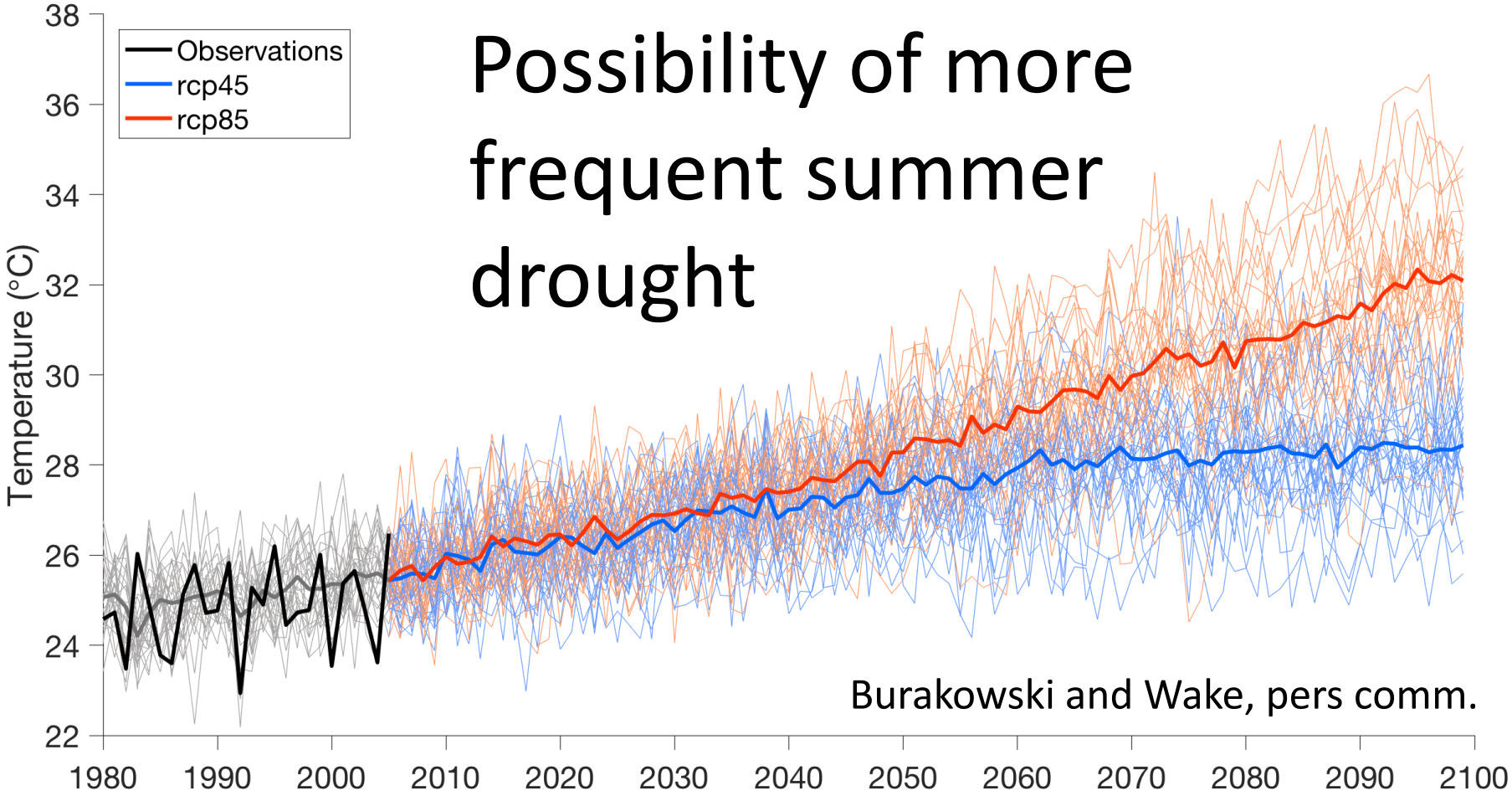
# More Frequent T'Storms from Wavier Jet



# Summer Rain is Projected to Remain Steady in the Future



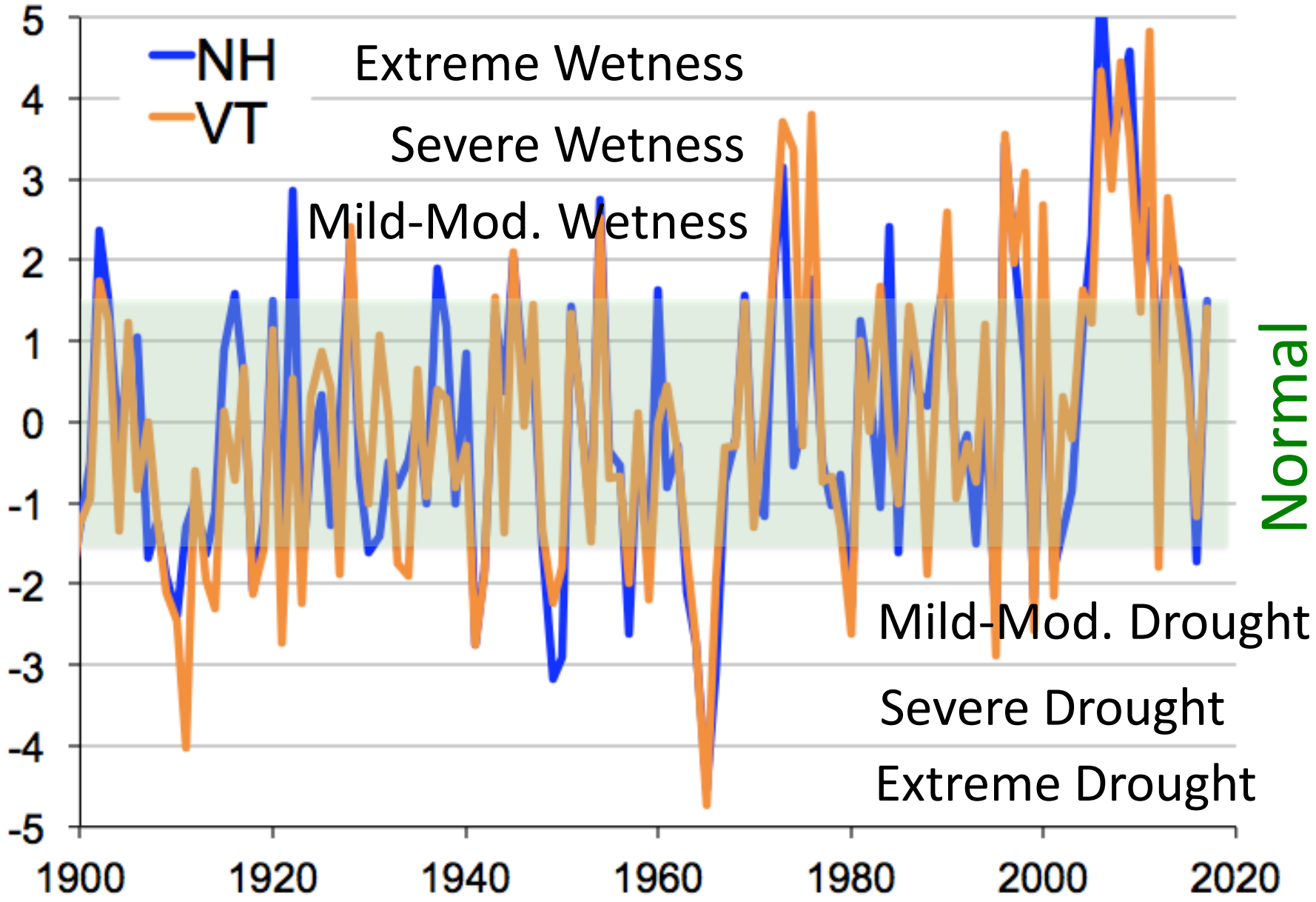
# And Summer Temperatures are Projected to Increase 5-12°F!



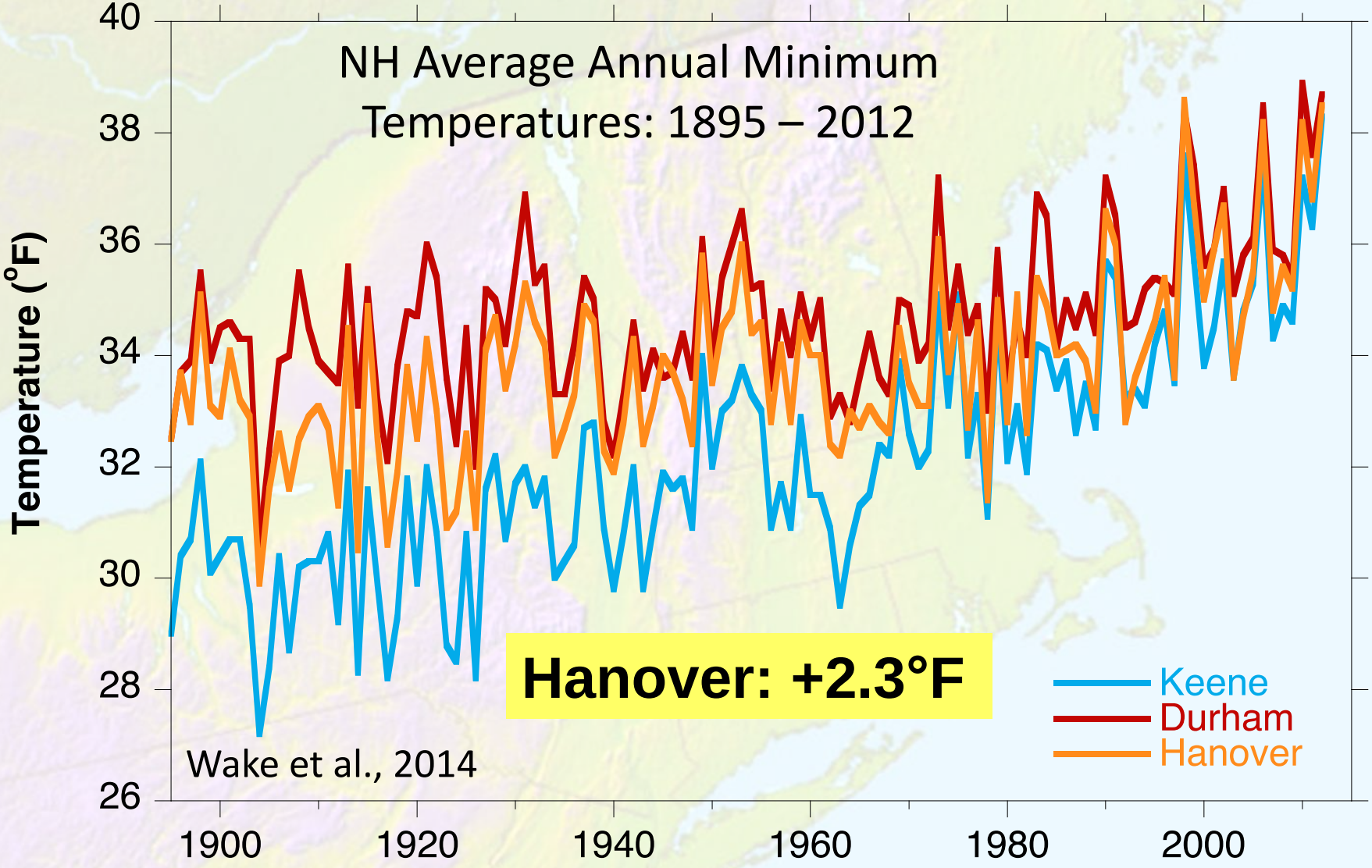
# Take Home Messages

- Downpours (extreme rainfall) jumped up 50% in 1996
  - Caused by Hurricanes, Nor'easters and thunderstorms
- Drought is more frequent in NH & VT than you may think and has real impacts
- The future:
  - More downpours likely
  - More summer drought is possible

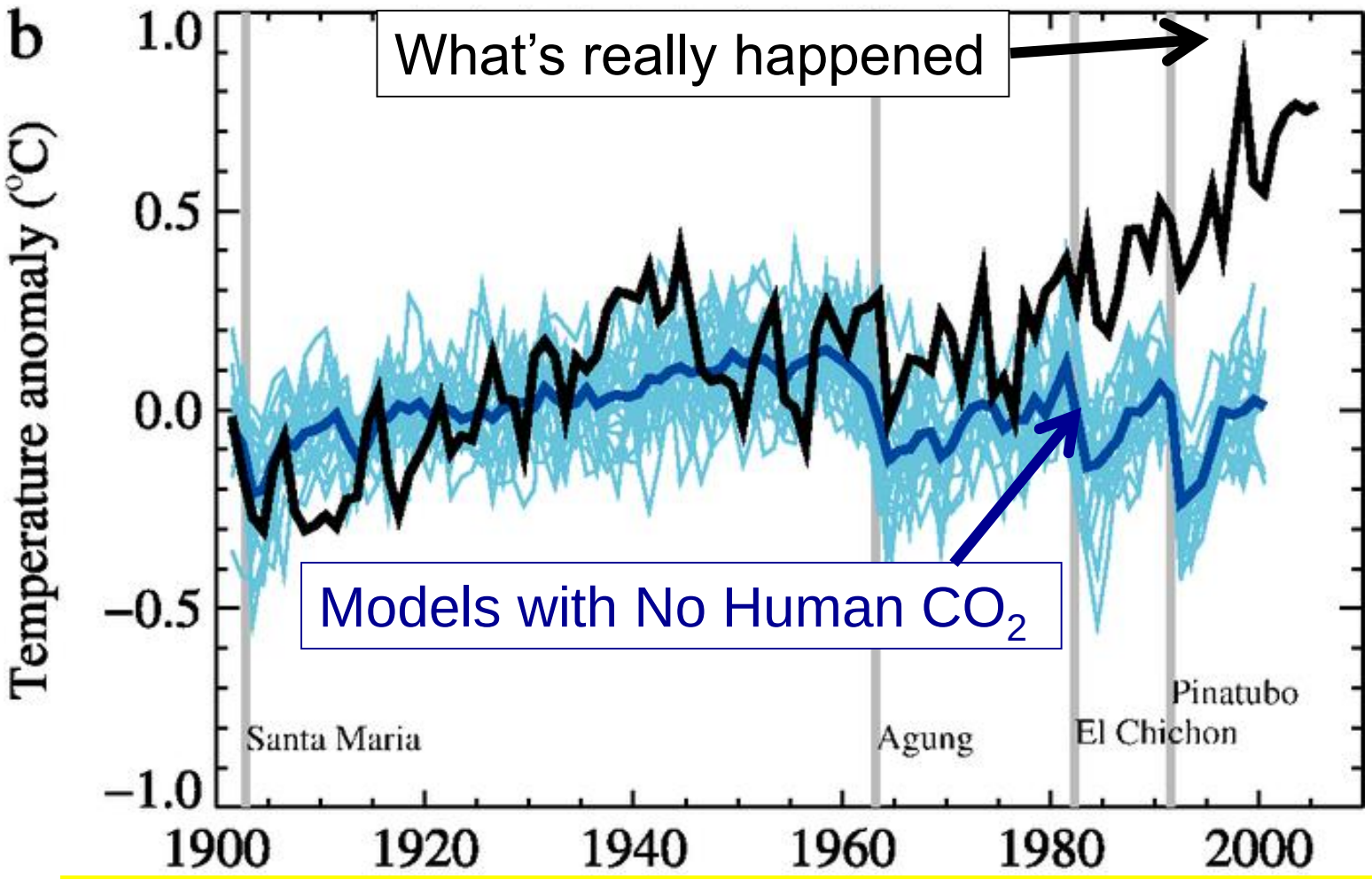
# NH & VT Drought and Wetness History



# NH/VT has Warmed: 2-4ºF since 1895
# Winter is Warming the Fastest

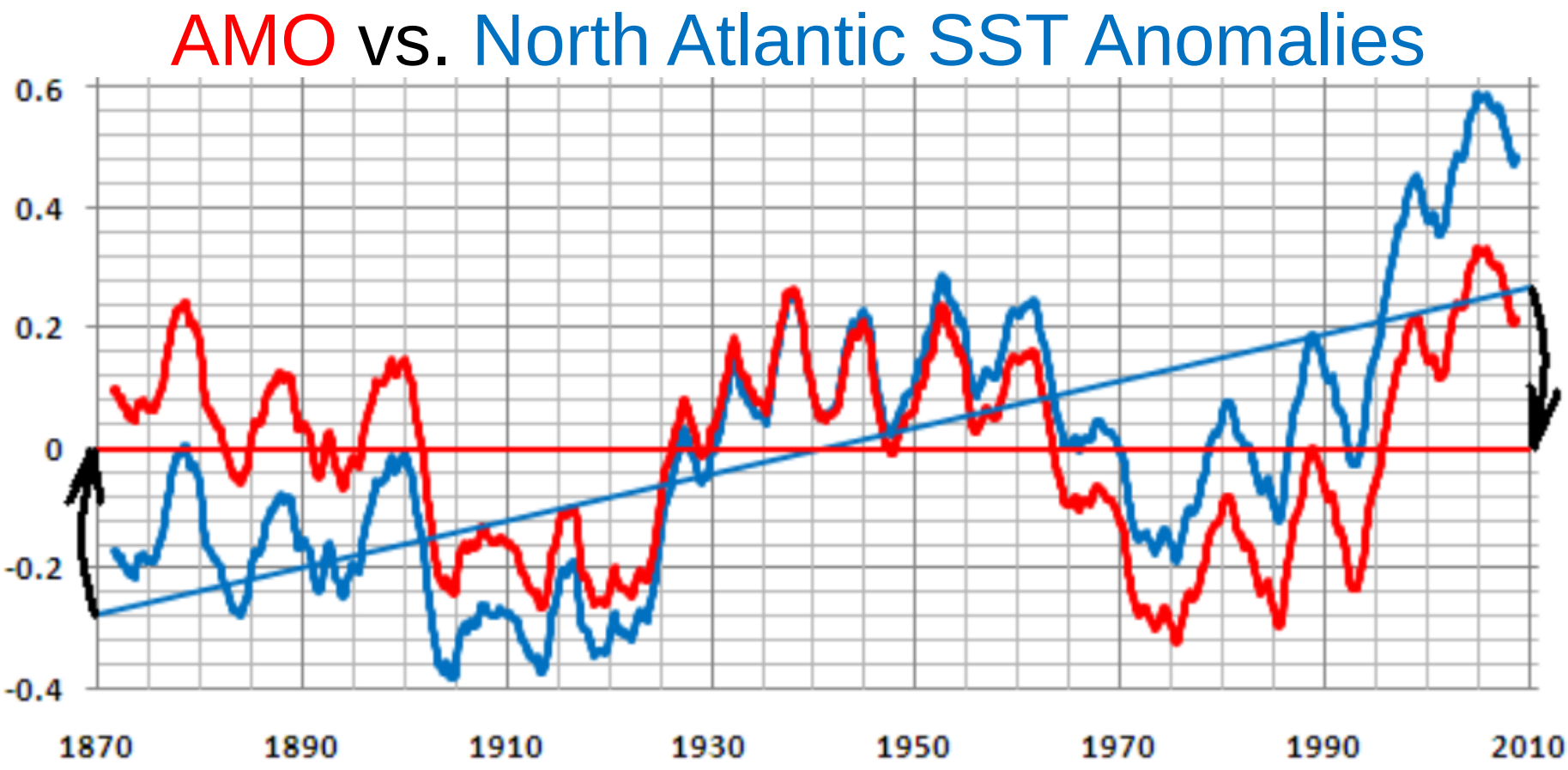


# Warming since 1970 Can Only be Explained with Human Greenhouse Gases




***Bottom Line:*** In order to explain temperature rise since ~1960, one MUST include human $CO_2$.

# Not All the Atlantic Ocean Warming is from Human Activities

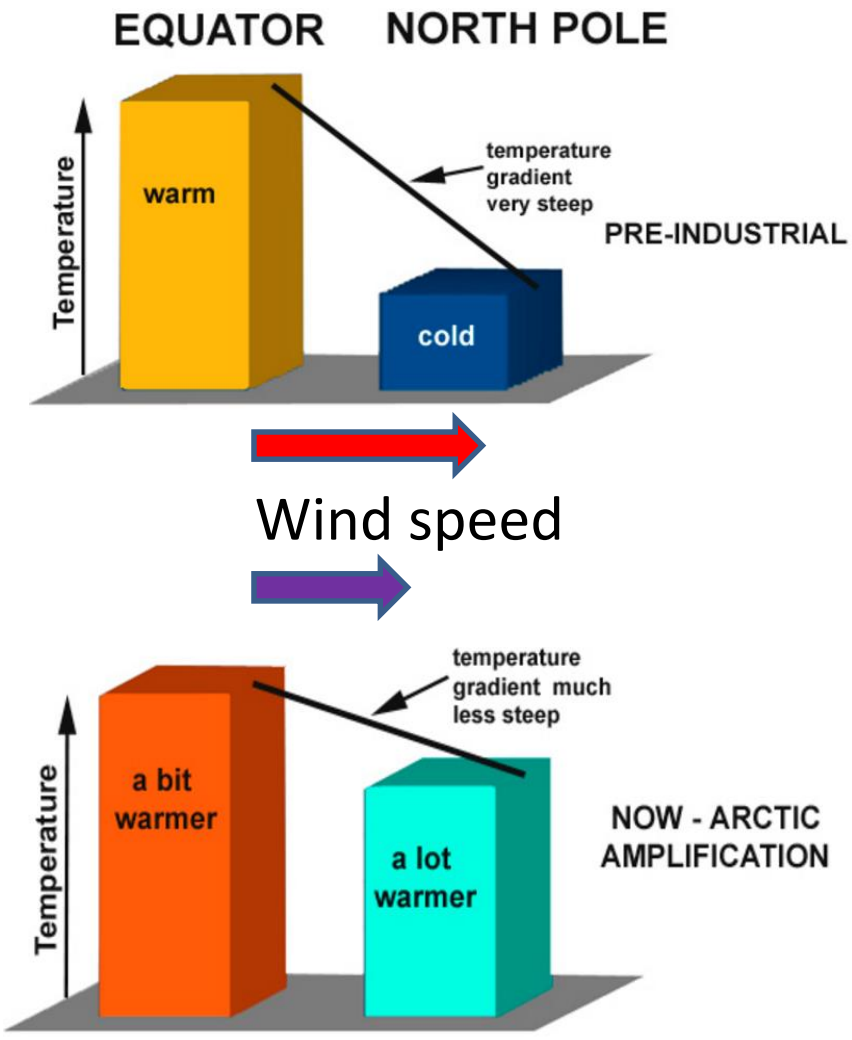


# Arctic Amplification Causes Wavier Jet Stream?

Arctic Amplification(AA) leads to decreased pressure gradient and weaker winds.

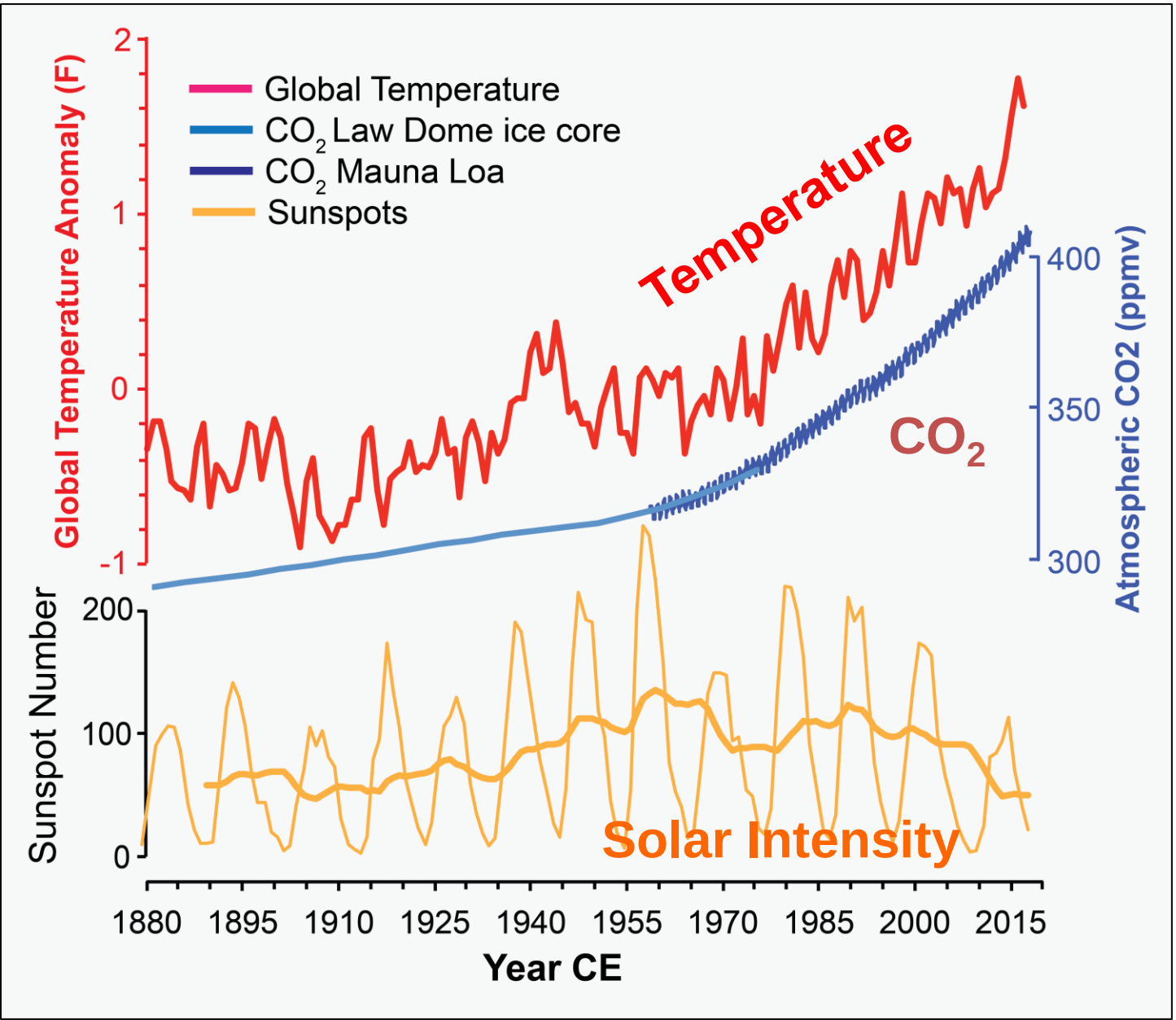
May cause wavier jet steam and more extreme thunderstorms and Nor'Easters

(Francis and Vavrus 2012; Cohen et al., 2018)




https://skepticalscience.com/jetstream-guide.html

# Solar Radiation Contributed to Early 20th Century Warming, but Sun has been Weakening since 1960

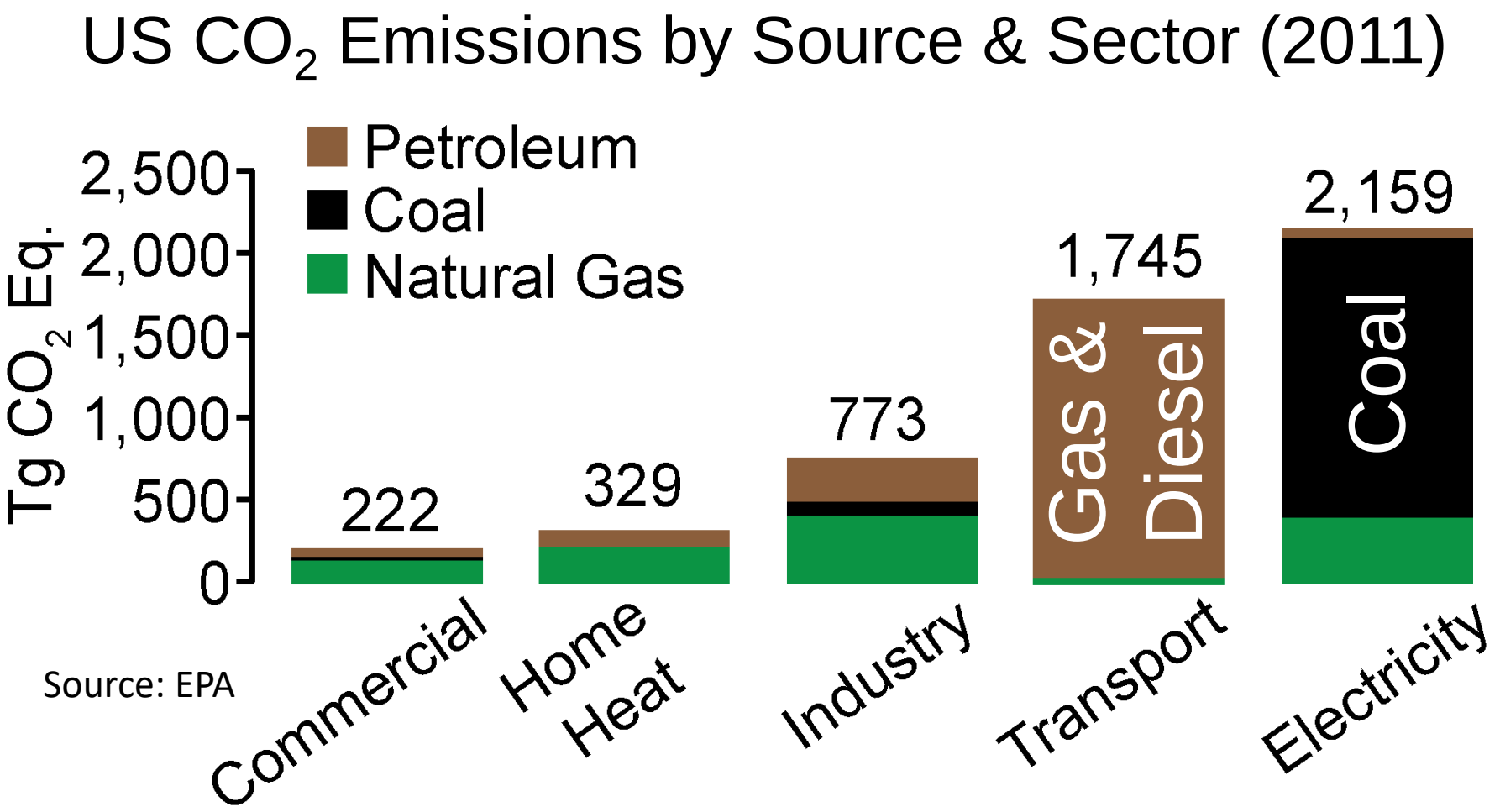



**Warming since 1960 is NOT from the Sun!!**

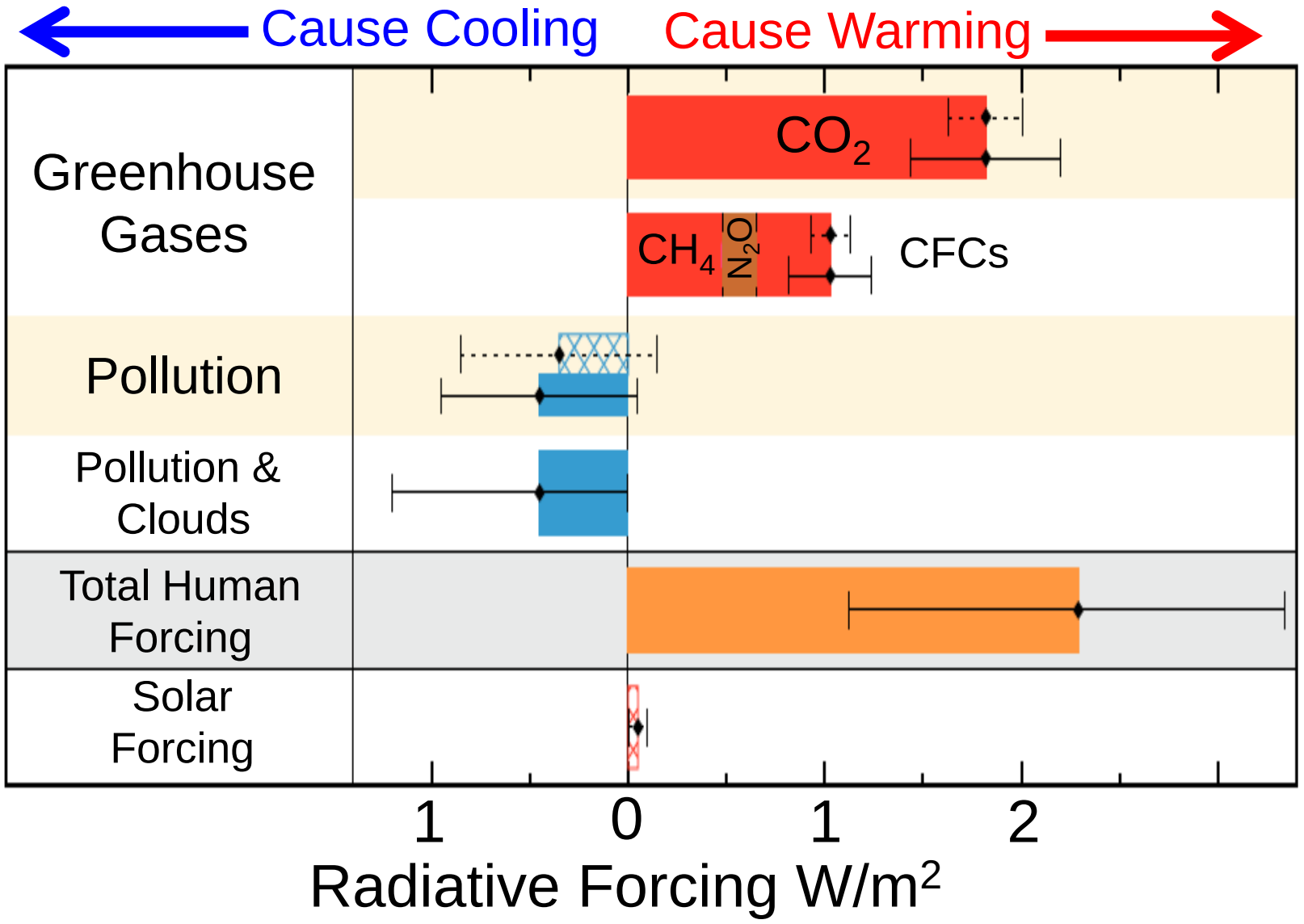
**Solar radiation has been *declining* since 1960**

# Most $CO_2$ is from Electricity and Transportation

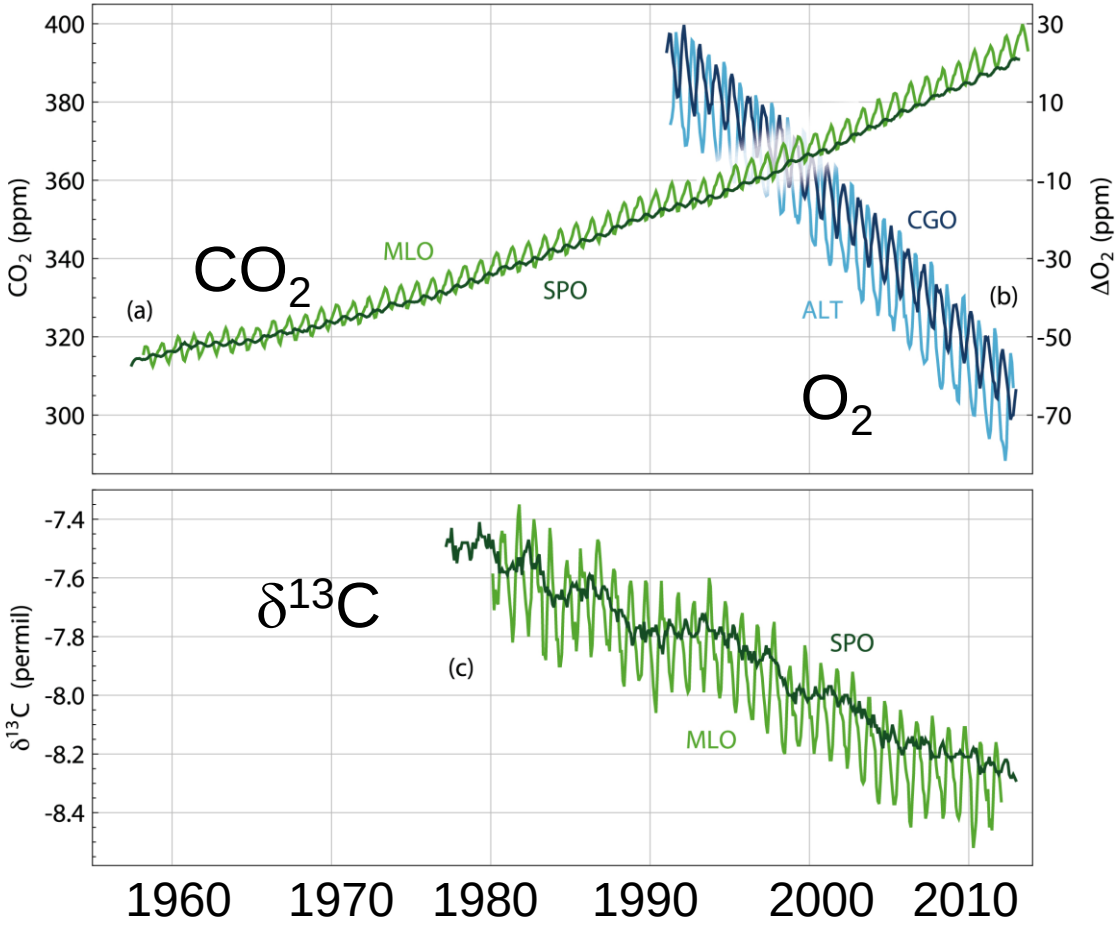
Coal produces 2x as much $CO_2$ per BTU as Natural Gas
Coal produces 1.5x as much $CO_2$ per BTU as Oil



# Climate Forcing from 1750-2011



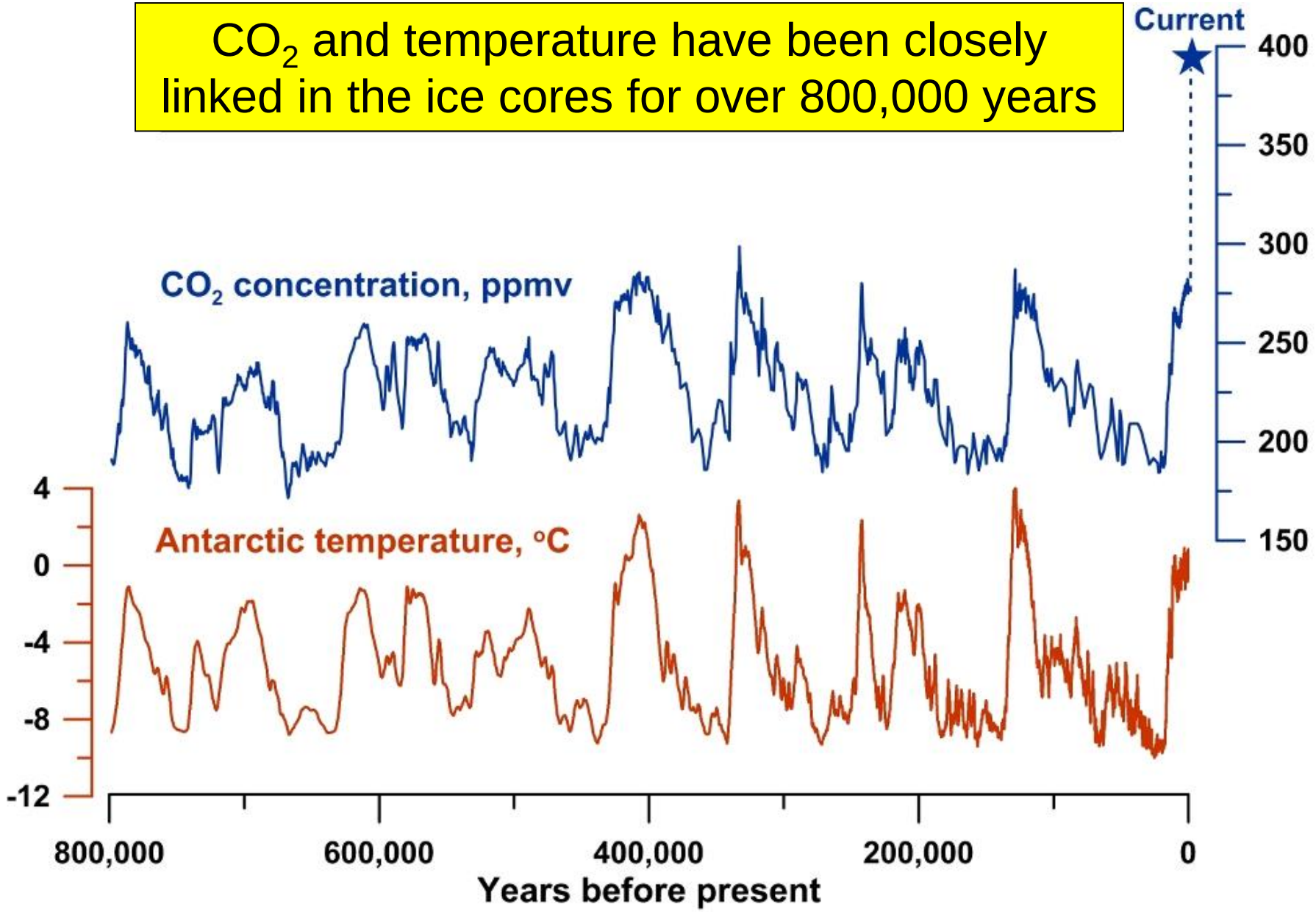
# Some $CO_2$ Facts



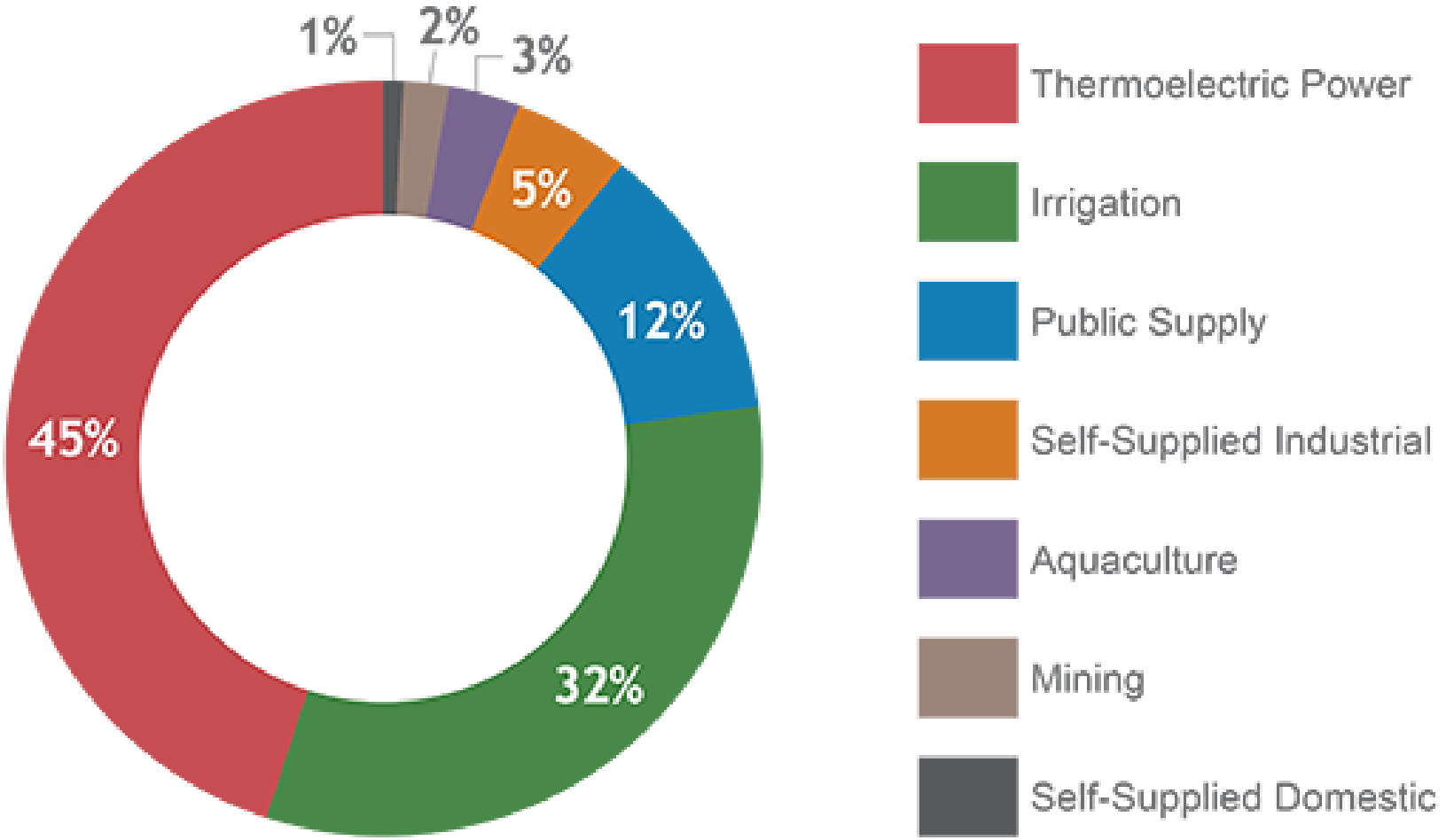

- Humans emit ***100+ TIMES*** more $CO_2$ than
- $CO_2$ has a fossil fuel chemical fingerprint
- $CO_2$ traps heat, raising temp.
- Without $CO_2$ Earth's average temp = -5ºF!! (today = 57ºF)

# Temperature and $CO_2$ are Closely Linked

$CO_2$ and temperature have been closely linked in the ice cores for over 800,000 years



# U.S. Freshwater Withdrawals (2010)



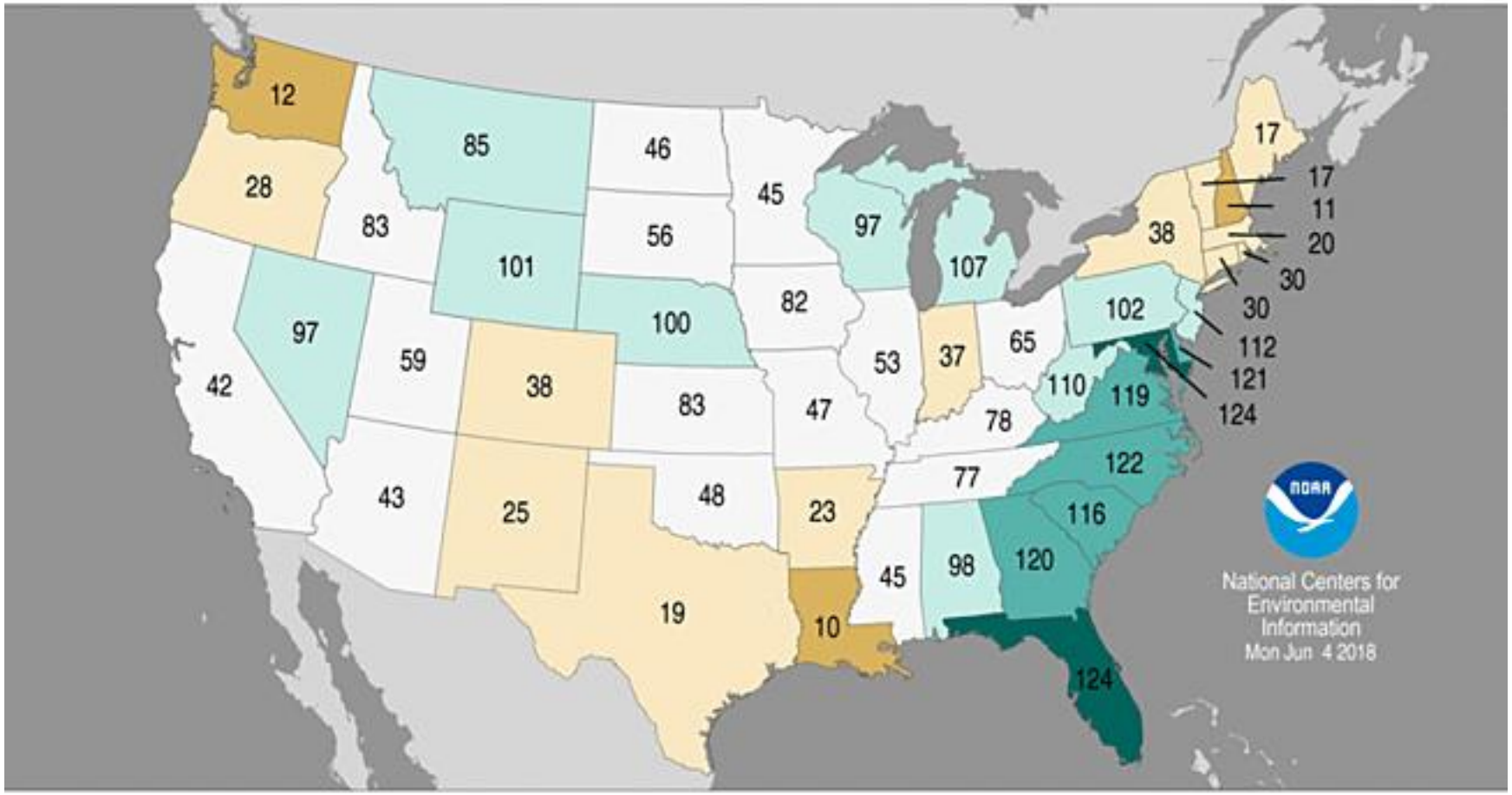

*Livestock is approximately less than 1% of total use and is not included.

*Data comes from Maupin, M.A., Kenny, J.F., Hutson, S.S., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2014, Estimated use of water in the United States in 2010: U.S. Geological Survey Circular 1405, 56 p., http://dx.doi.org/10.3133/cir1405.

# Statewide Precipitation Ranks

May 2018

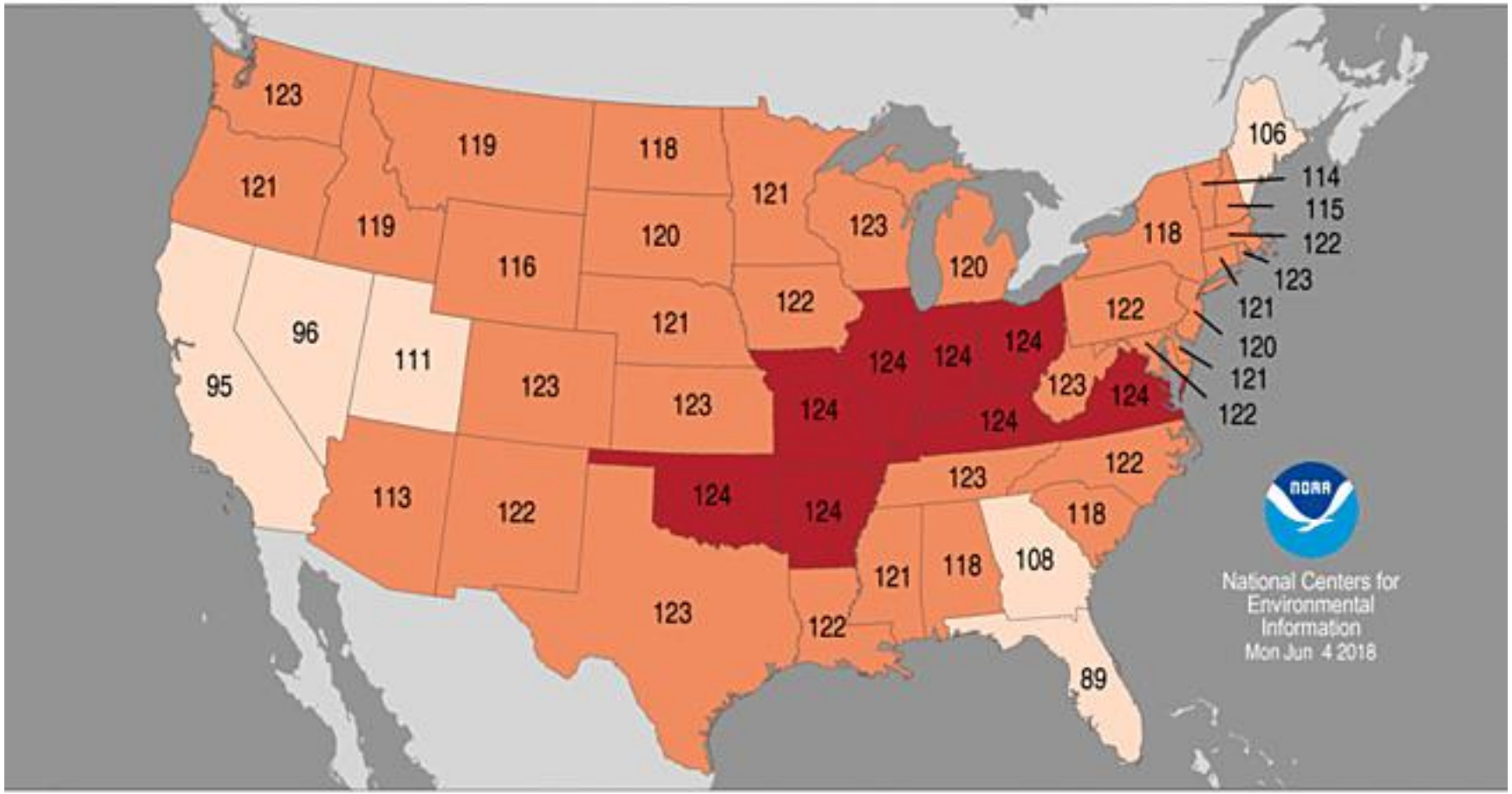
Period: 1895–2018



# Statewide Average Temperature Ranks

May 2018

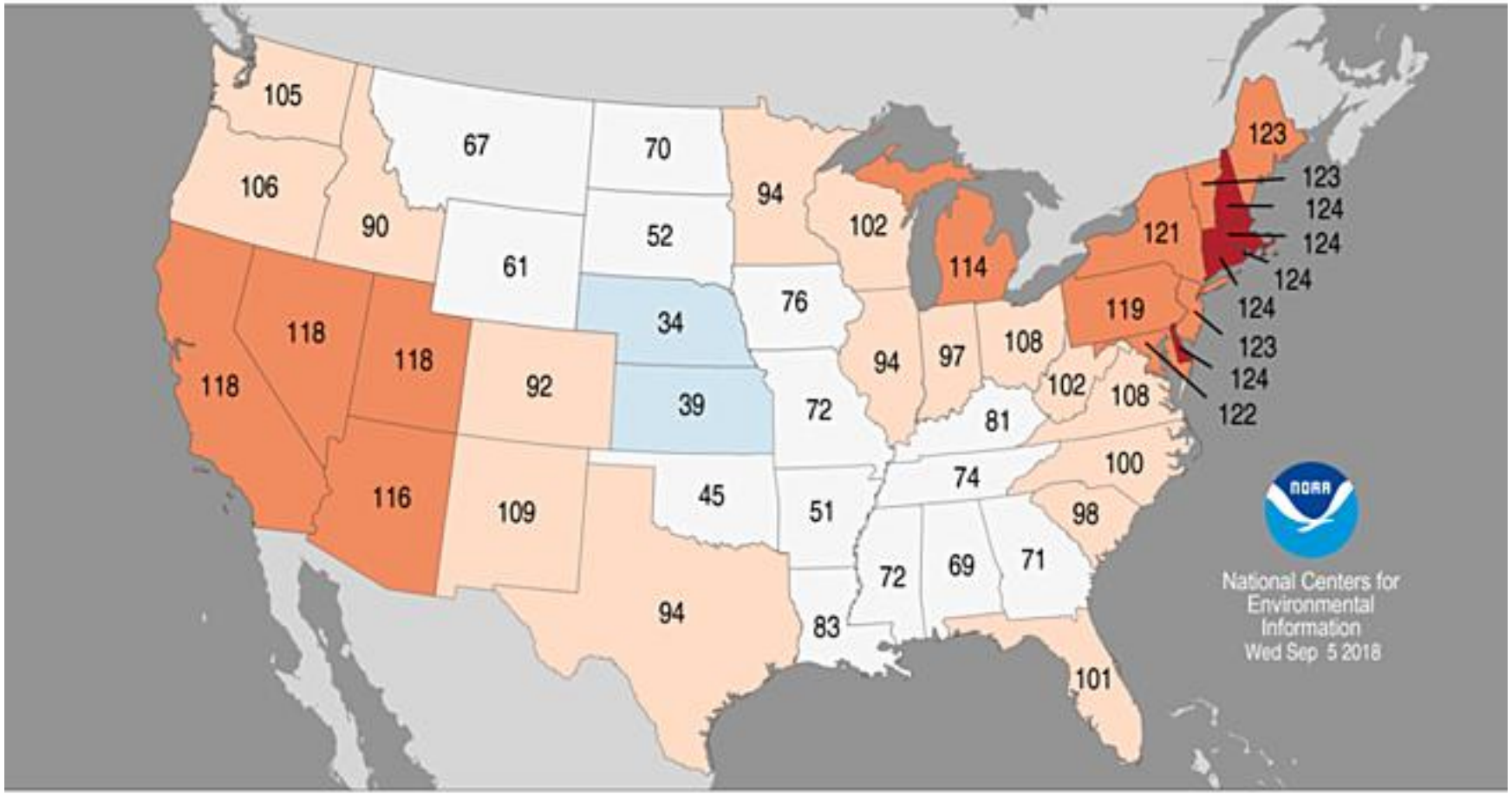
Period: 1895–2018



# Statewide Average Temperature Ranks

## August 2018

Period: 1895–2018



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## August 2018

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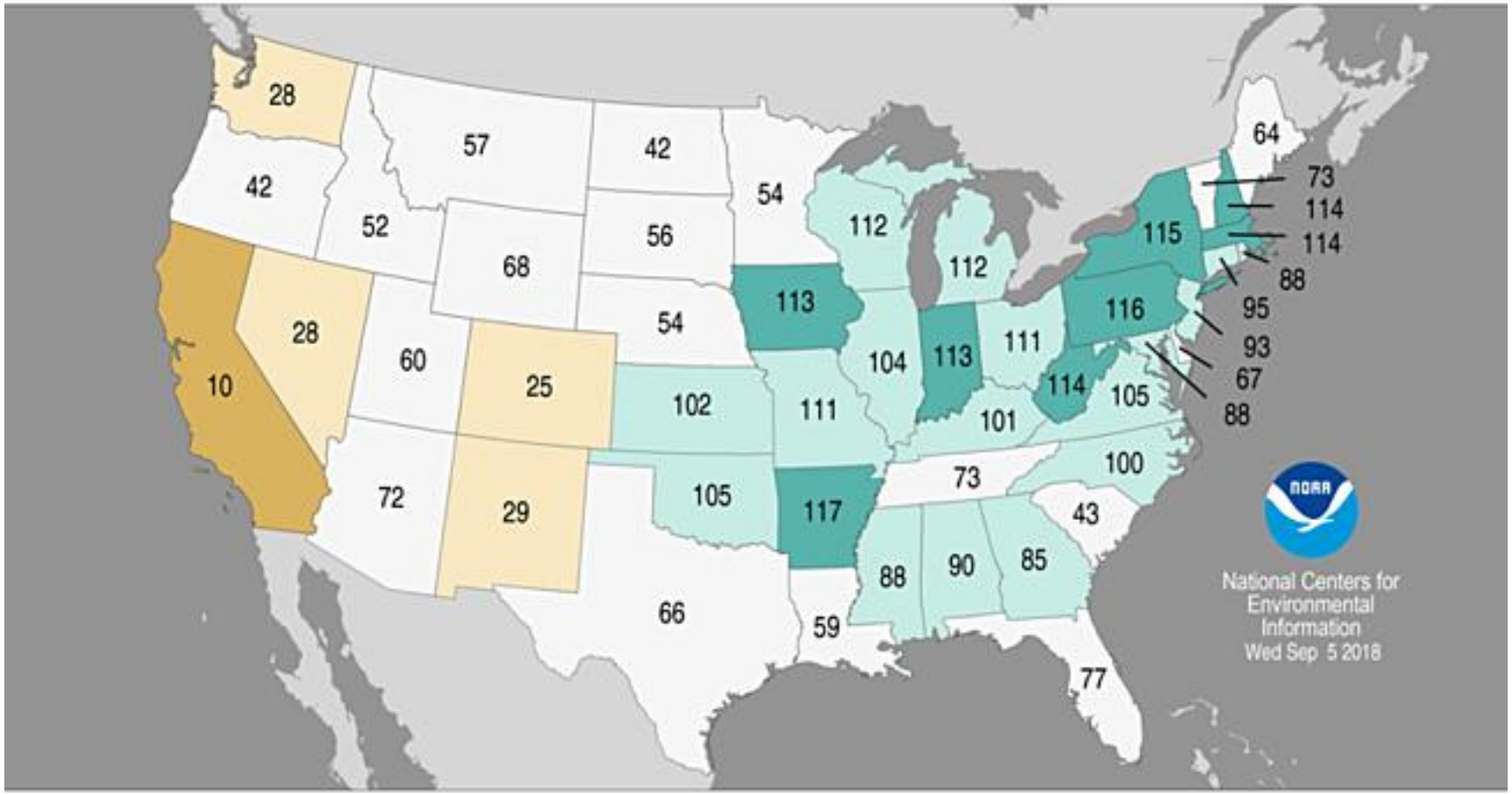

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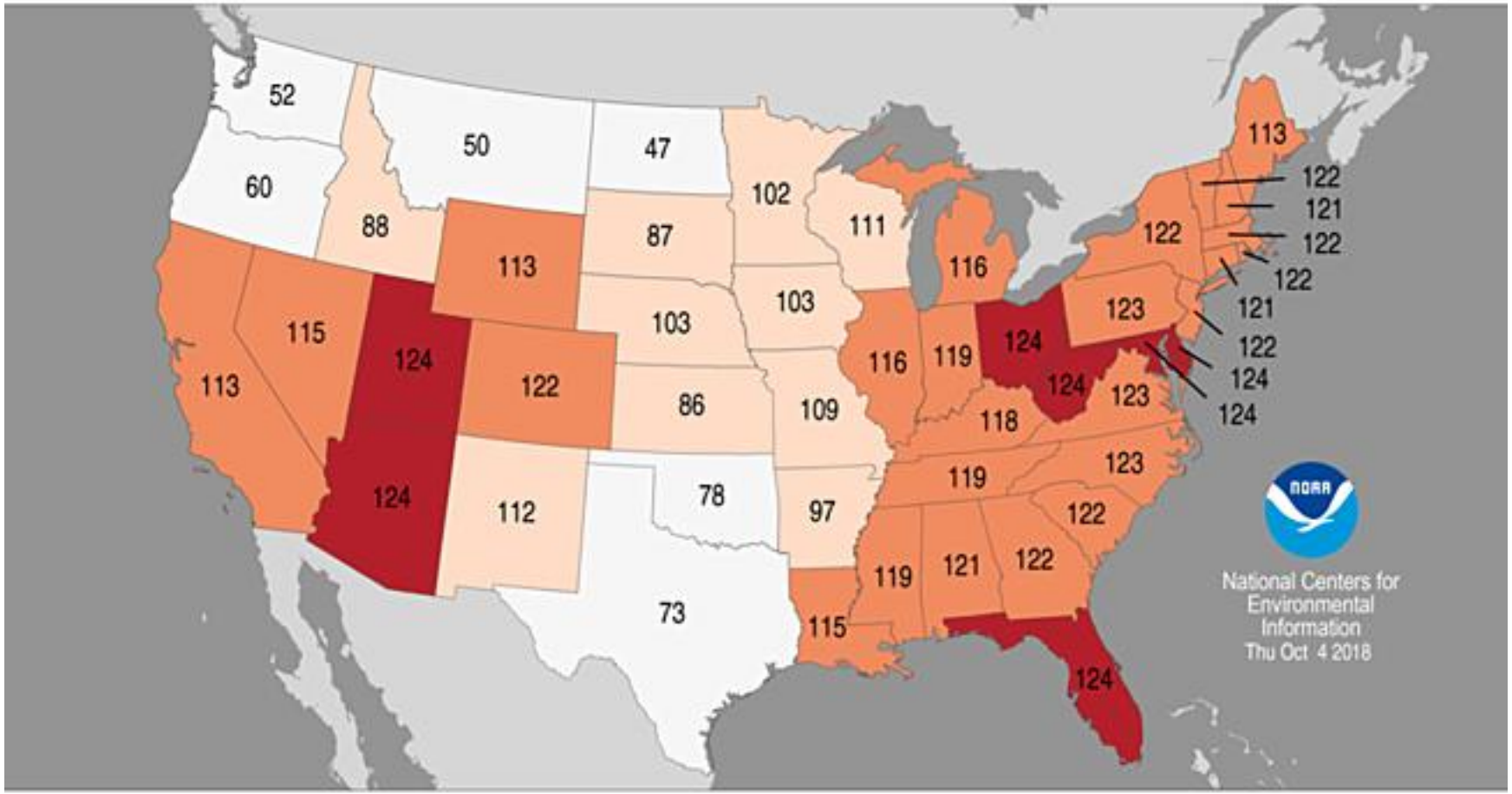

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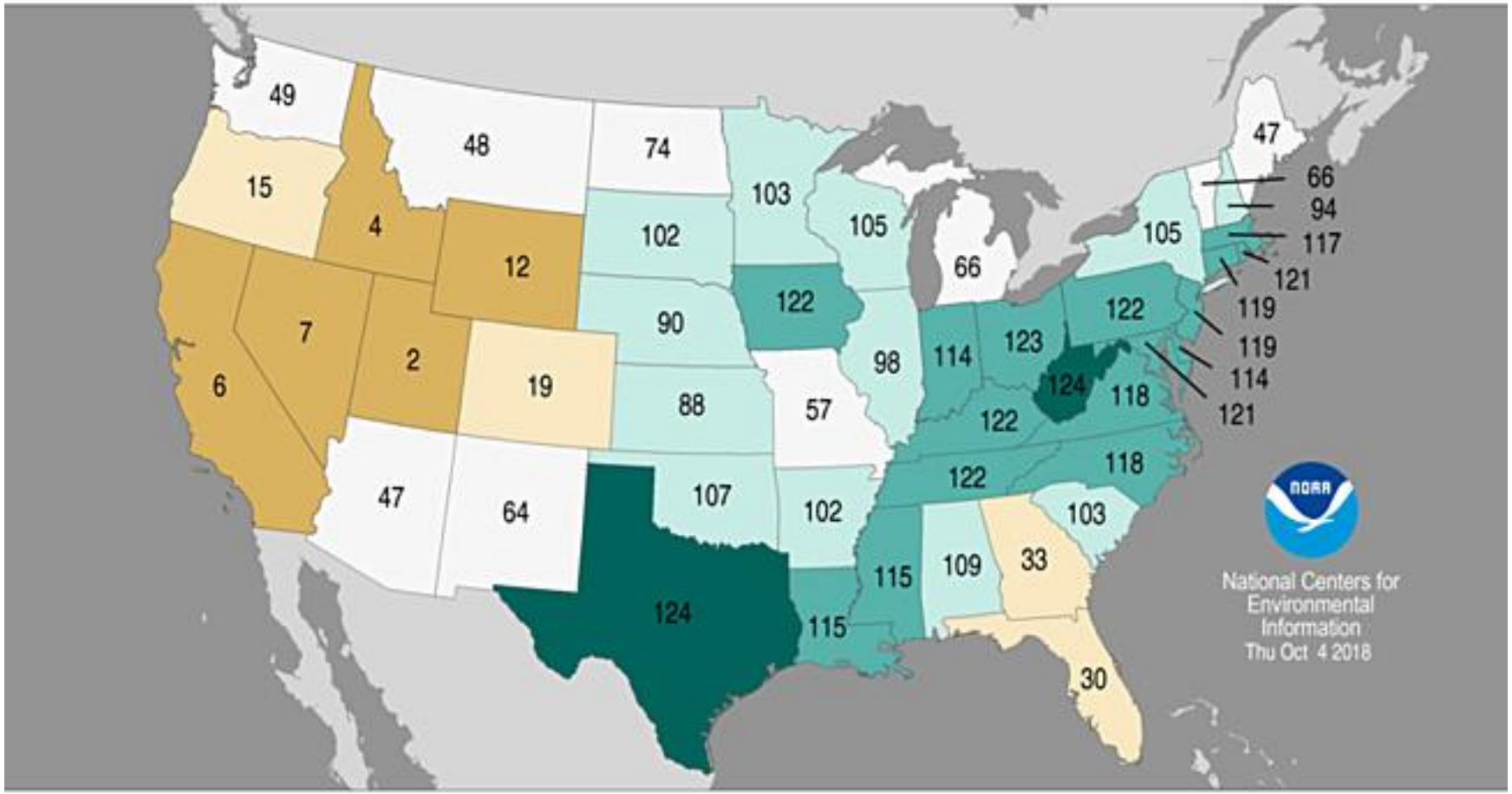
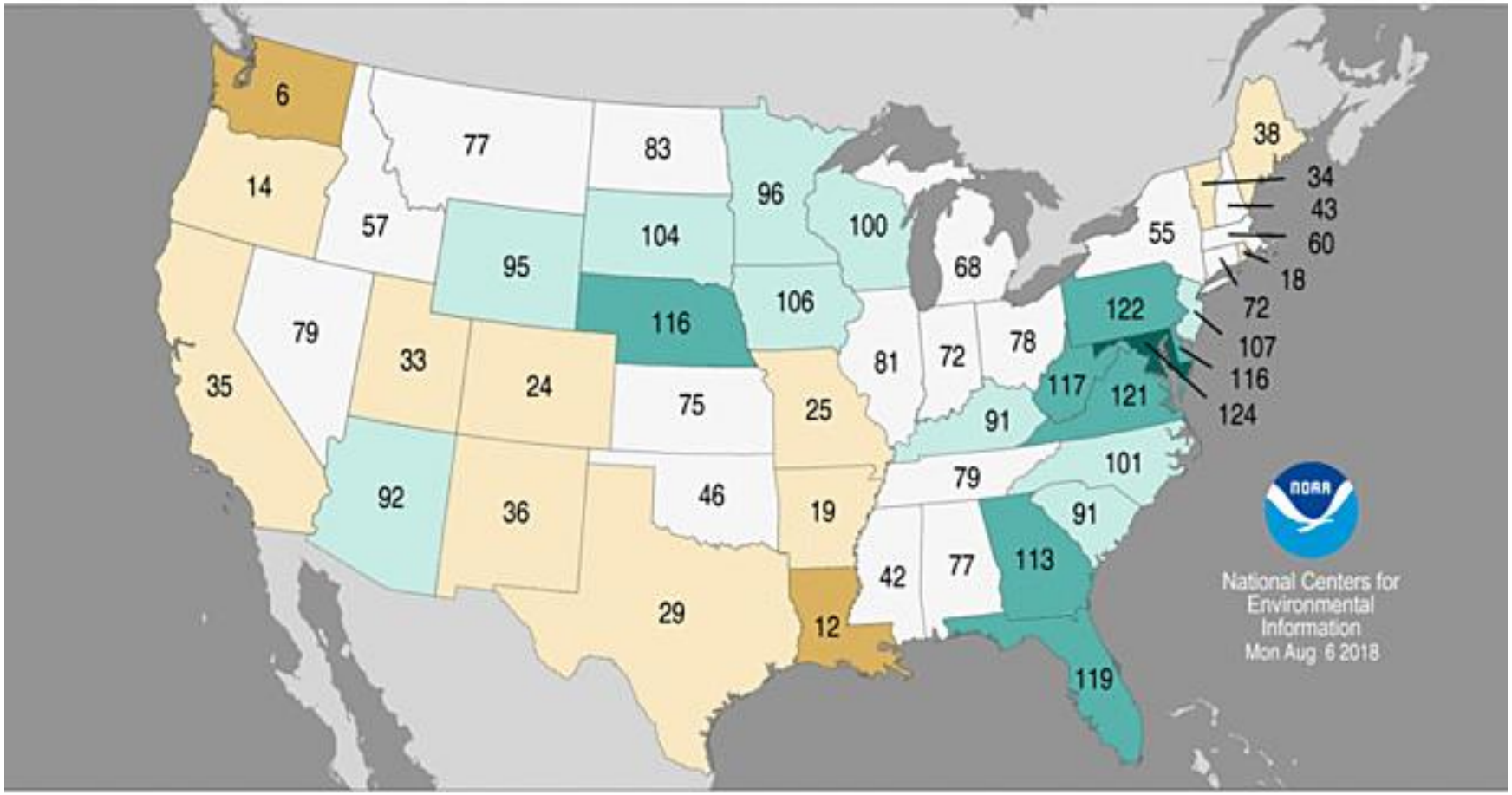


# Statewide Precipitation Ranks

## May–July 2018

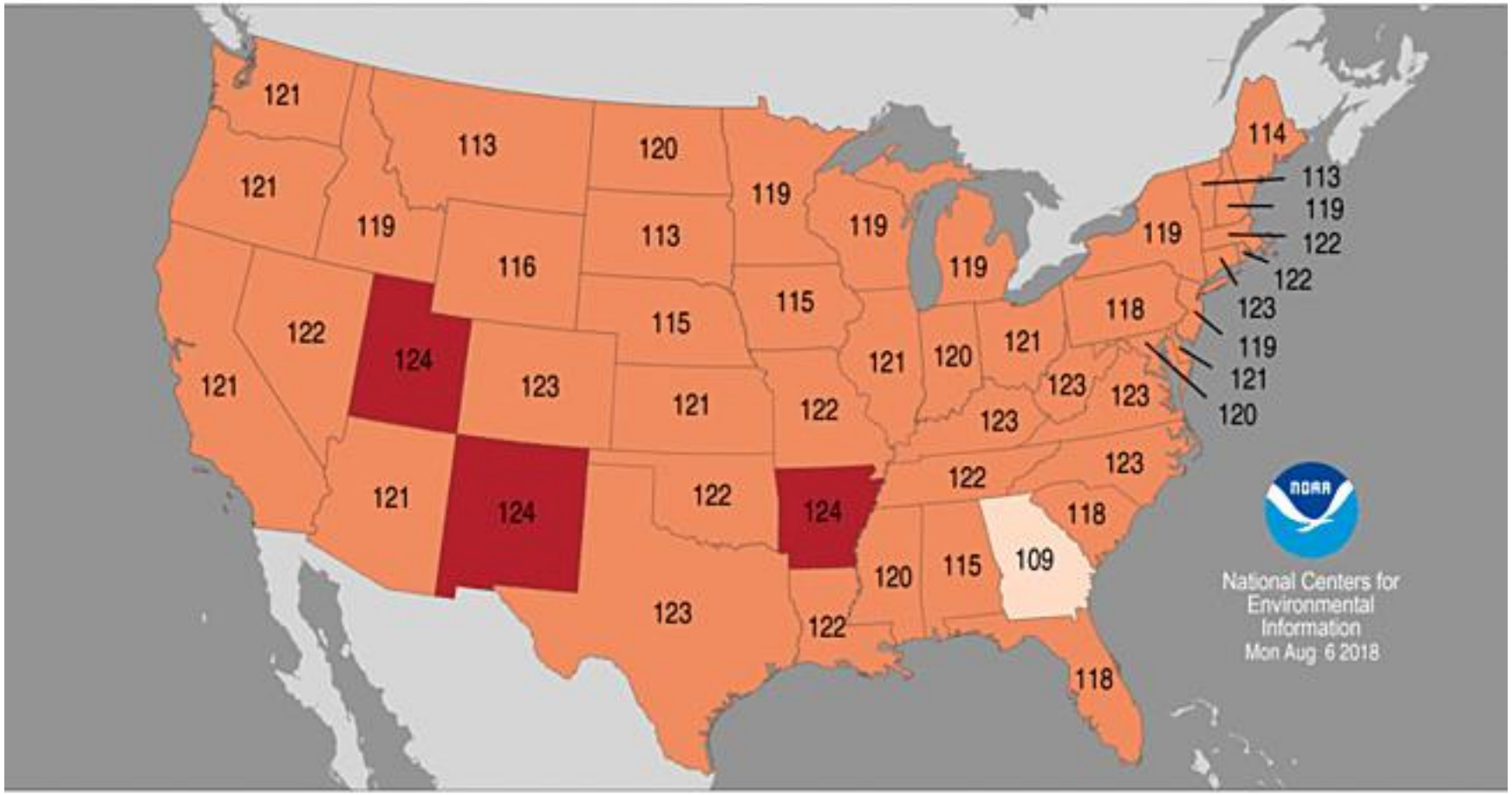
Period: 1895–2018



# Statewide Average Temperature Ranks

## May–July 2018

Period: 1895–2018




Record Coldest ( 1 )

Much Below Average

Below Average

Near Average

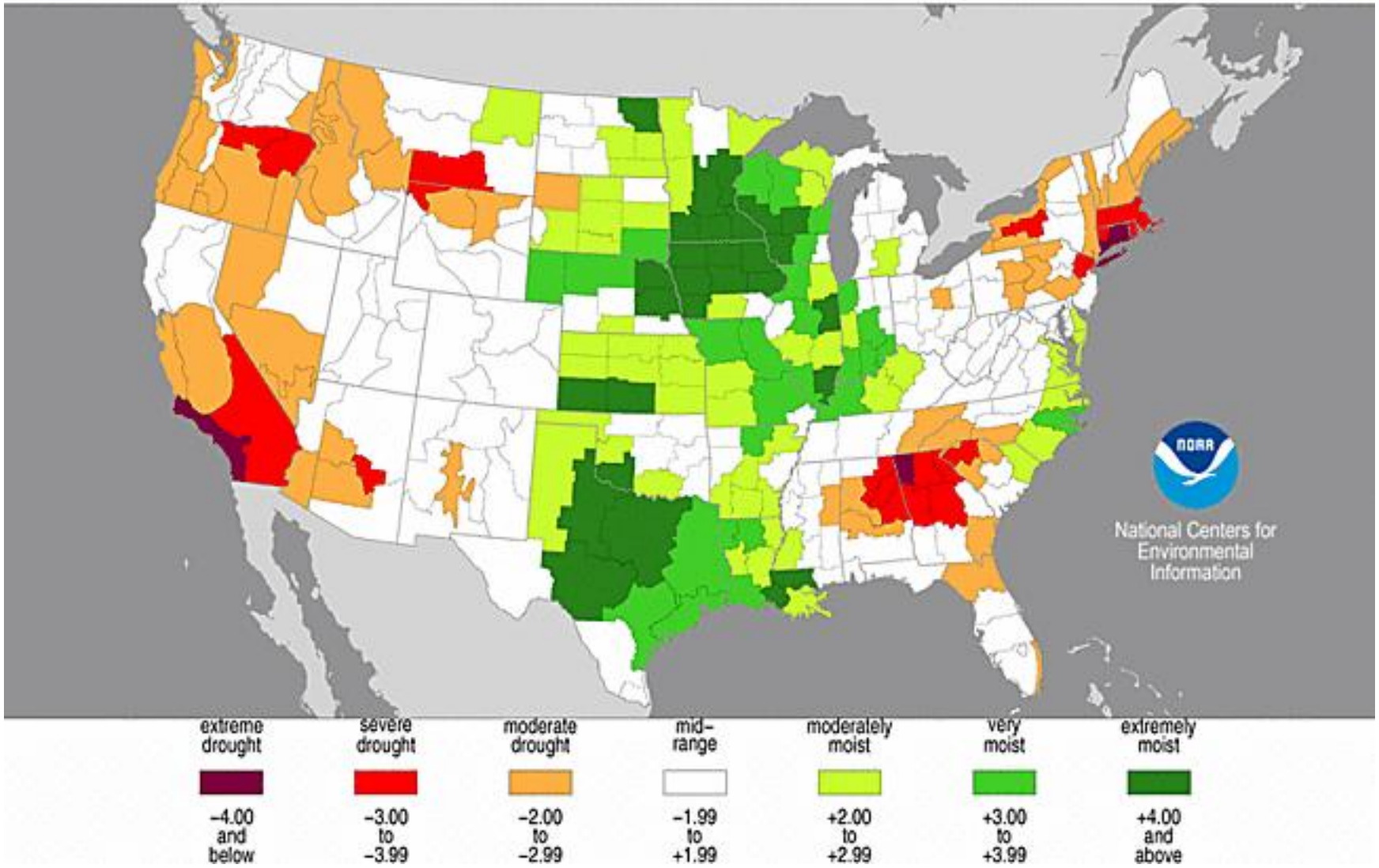
Above Average

Much Above Average

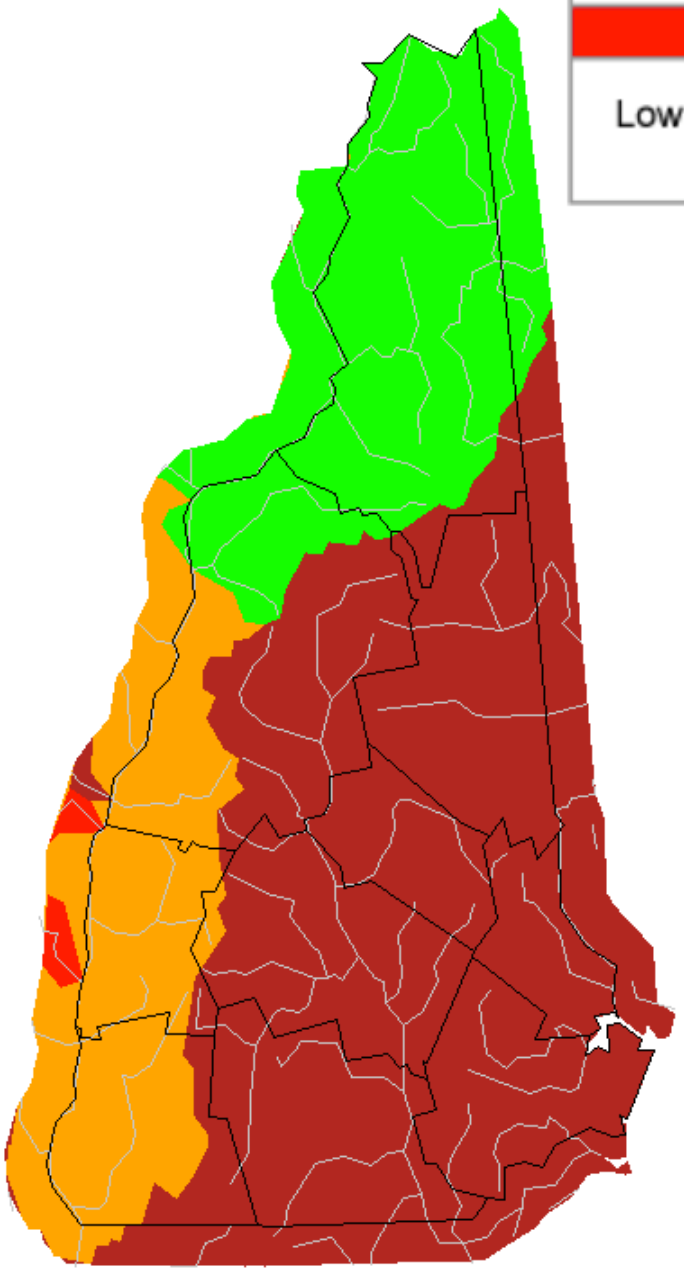
Record Warmest ( 124 )

# Palmer Drought Severity Index

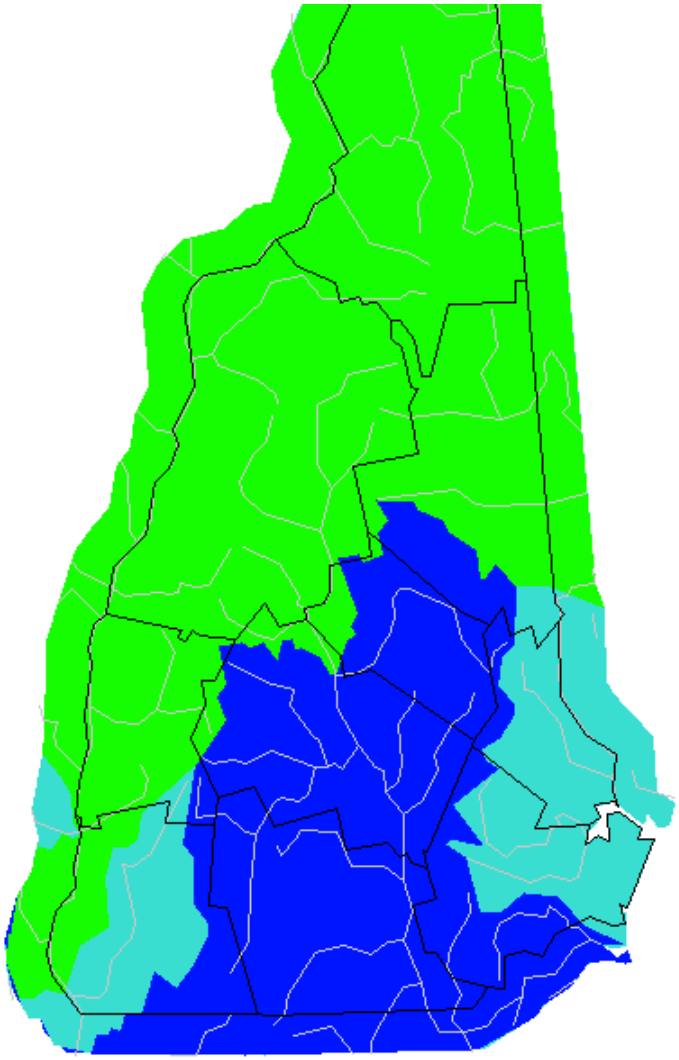
September, 2016



September 2016



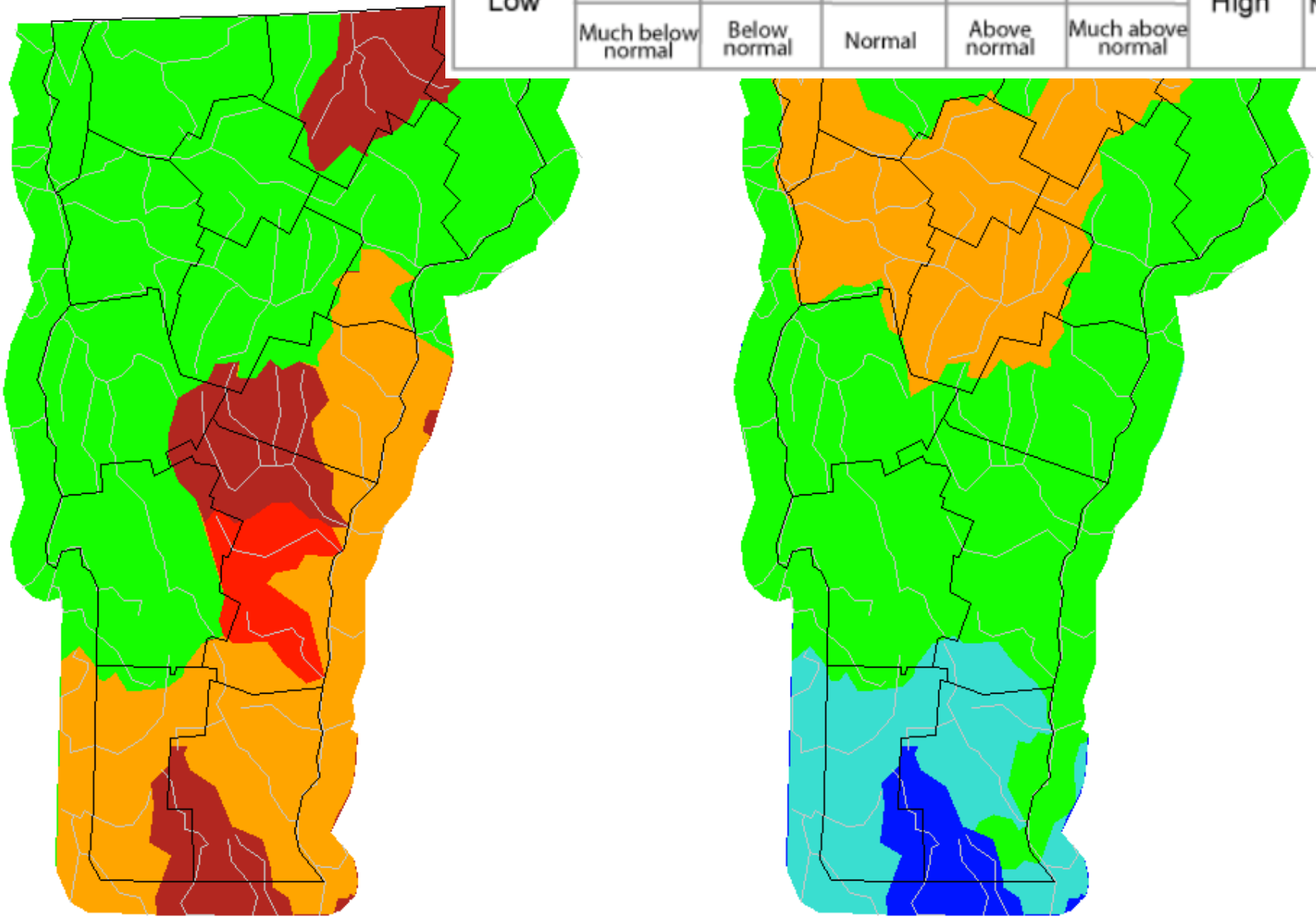
| Explanation - Percentile classes | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Low | <10 | 10-24 | 25-75 | 76-90 | >90 | High | No Data |
| | Much below normal | Below normal | Normal | Above normal | Much above normal | | |



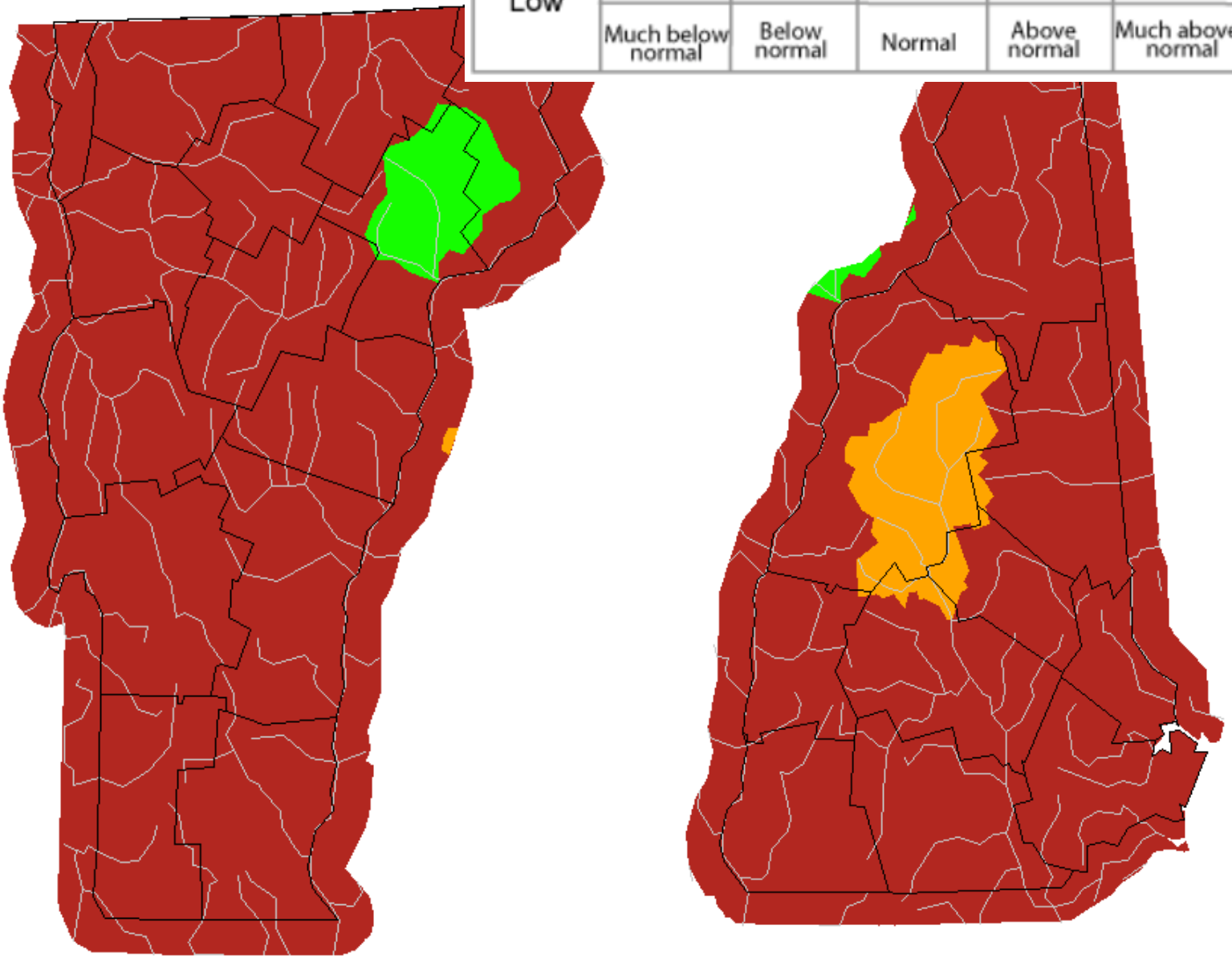
USGS

USGS

September 2016



July 1965




USGS

| Category | Description | Possible Impacts |
|---|---|---|
| D0 | Abnormally Dry | Going into drought:<br>▪ short-term dryness slowing planting, growth of crops or pastures<br>Coming out of drought:<br>▪ some lingering water deficits<br>▪ pastures or crops not fully recovered |
| D1 | Moderate Drought | ▪ Some damage to crops, pastures<br>▪ Streams, reservoirs, or wells low, some water shortages developing or imminent<br>▪ Voluntary water-use restrictions requested |
| D2 | Severe Drought | ▪ Crop or pasture losses likely<br>▪ Water shortages common<br>▪ Water restrictions imposed |
| D3 | Extreme Drought | ▪ Major crop/pasture losses<br>▪ Widespread water shortages or restrictions |
| D4 | Exceptional Drought | ▪ Exceptional and widespread crop/pasture losses<br>▪ Shortages of water in reservoirs, streams, and wells creating water emergencies |

# Hurricane Irene: August, 2011


~50% of the jump since 1996 is from MORE hurricane events with warmer ocean waters and higher water vapor

# July 2013 & 2017 Thunderstorms

+3” Rain for Each Event


~25% of the jump since 1996 is from MORE T’storm evens with wavier jetstream

| Type of Use | Gallons per Capita | Percentage of Total Daily Use |
|---|---|---|
| Showers | 8.8 | 19.5% |
| Clothes Washers | 10.0 | 22.1% |
| Toilets | 8.2 | 18.0% |
| Dishwashers | 0.7 | 1.5% |
| Baths | 1.2 | 2.7% |
| Leaks | 4.0 | 8.8% |
| Faucets | 10.8 | 23.9% |
| Other Domestic Uses | 1.6 | 3.4% |

Source: Handbook of Water Use and Conservation, Amy Vickers